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OUR REF: 9847-0001-6X PCT
GROUP ART UNIT: 2834

Re: Inventor: MATS LEIJON ET AL
Serial No: 09/147,325
Filed: FEBRUARY 17, 1999
For: ROTATING ELECTRICAL MACHINE ...

#20

SIR:

Attached hereto for filing are the following papers:

FILING OF DECLARATION UNDER 37 C.F.R. §1.132 AND FURTHER EVIDENCE IN SUPPORT OF PATENTABILITY
DECLARATION UNDER 37 C.F.R. §1.132 OF ROBERT L. HIRT WITH ATTACHED APPENDICES 1-6
DECLARATION UNDER 37 C.F.R. §1.132 OF ROBERT E. FENTON WITH ATTACHED APPENDICES A-E

Our check in the amount of $ 0.00 is attached covering any required fees. In the event any variance exists between the amount enclosed and the Patent Office charges for filing the above-noted documents, including any fees required under 37 CFR 1.136 for any necessary Extension of Time to make the filing of the attached documents timely, please charge or credit the difference to our Deposit Account No. 15-0030. Further, if these papers are not considered timely filed, then a petition is hereby made under 37 C.F.R. 1.136 for the necessary extension of time. A duplicate copy of this sheet is enclosed.

Respectfully submitted,

OBLON, SPIVAK, McCLELLAND,
MAIER & NEUSTADT, P.C.

Bradley D. Lytle
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DOCKET NO: 9847-0001-6X PCT
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IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF: :

MATS LEIJON ET AL. : GROUP ART UNIT: 2834

SERIAL NO: 09/147,325 :

FILED: FEBRUARY 17, 1999 : EXAMINER: ENAD, E.

FOR: ROTATING ELECTRICAL MACHINE COMPRISING HIGH-VOLTAGE STATOR WINDING AND ELONGATED SUPPORT DEVICES SUPPORTING THE WINDING AND METHOD FOR MANUFACTURING SUCH MACHINE

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FILING OF DECLARATIONS UNDER 37 C.F.R. §1.132, AND FURTHER EVIDENCE IN SUPPORT OF PATENTABILITY

ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, D.C. 20231

SIR:

Supplemental to the Amendment filed on March 29, 2001, Applicants respectfully request that the following remarks, and 37 C.F.R. §1.132 Declarations filed herewith, be taken into account when reconsidering the claim rejections set forth in the Official Action mailed September 29, 2000.

REMARKS

Favorable reconsideration of this application is respectfully requested in view of (1) the amendments and remarks made in the Amendment filed March 29, 2001, (2) the 37 C.F.R. §1.132 Declarations filed herewith, and (3) the following discussion.

Claims 77-158 are pending, Claims 77-79, 81, 83-89, 94-96, 98, 99, 101-103, 114, 116-120, 123-127, 129, 133, 136, 137, 139, 143, and 153 having been amended, and Claims 154-158 having been added by way of the present amendment.

In the outstanding Office Action, Claims 91, 93, and 124 were rejected under 35 U.S.C. §112, first paragraph; Claims 77, 121, 122, 133, and 143 were rejected under 35 U.S.C. §112, second paragraph; Claims 77-84, 87-93, 103-112, 116-125, 127, 129, 130, 136, and 153 were rejected under 35 U.S.C. §103(a) as being unpatentable over Shildneck (U.S. Patent No. 3,014,139) in view of Elton et al. (U.S. Patent No. 4,853,565, hereinafter Elton), and further in view of Wood (British Patent No. 1,135,242); Claims 85 and 86 were rejected under 35 U.S.C. §103(a) as being unpatentable over Shildneck in view of Elton and Wood, and further in view of Mazzorana (French Patent Nos. 2,594,271 and 2,556,146); Claims 94-102, 126, 128, 131-135, 137-144, and 148-152 were rejected under 35 U.S.C. §103(a) as being unpatentable over Shildneck in view of Elton and Wood, and further in view of Grant (U.S. Patent No. 5,325,008); Claims 113-115 were rejected under 35 U.S.C. §103(a) as being unpatentable over Shildneck in view of Elton and Wood, and further in view of Siemens (British Patent No. 468,827 (erroneously identified in the outstanding Office Action as a German patent)); and Claims 145-147 were rejected under 35 U.S.C. §103(a) as being unpatentable over Shildneck in view of Elton and Wood, and further in view of Madsen (U.S. Patent No. 3,932,779).

Filed herewith are declarations under 37 C.F.R. §1.132 of Mr. Robert Fenton, and Mr. Robert Hirt, providing additional evidence in support of patentability and to traverse the outstanding rejection.

MPEP § 706.02(j) sets forth the requirements for establishing a *prima facie* case of obviousness:

> To establish a *prima facie* case of obviousness, three basic criteria must be met. First, there must be some suggestion or motivation, either in the

> references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings. Second, there must be a reasonable expectation of success. Finally, the prior art reference (or references when combined) must teach or suggest all the claim limitations. The teaching or suggestion to make the claimed combination and the reasonable expectation of success must both be found in the prior art and not based on applicant's disclosure.

MPEP § 2142 also articulates the evidentiary standard for establishing a *prima facie* case of obviousness:

> The initial burden is on the examiner to provide some suggestion of the desirability of doing what the inventor has done. 'To support the conclusion that the claimed invention is directed to obvious subject matter, either the references must expressly or impliedly suggest the claimed invention or the examiner must present a convincing line of reasoning as to why the artisan would have found the claimed invention to have been obvious in light of the teachings of the references.' *Ex parte Clapp*, 227 USPQ 972, 973 (Bd. Pat. App. & Inter. 1985).
>
> . . . The ultimate determination of patentability is based on the entire record, by a preponderance of evidence, with due consideration to the persuasiveness of any arguments and any secondary evidence. *In re Oetiker*, 977 F.2d 1443 (Fed. Cir. 1992).
>
> . . . Facts established by rebuttal evidence must be evaluated along with the facts on which the conclusion of obviousness was reached, not against the conclusion itself. *In re Eli Lilly & Co.*, 902 F.2d 943 (Fed. Cir. 1990).

The first prong of a *prima facie* case of obviousness requires that the prior art, or information generally known by one of ordinary skill in the art, must suggest the desirability of the claimed invention. The Office Action of September 29, 2000, at paragraph 3, attempts to establish this prong by asserting the following:

> . . . it would have been obvious to one having ordinary skill in the art at the time the invention was made to have used the high voltage cable as taught by Elton et al. as winding conductors to the stator as disclosed by Shildneck since such a modification according to Elton et al. would provide a cable that is flexible, prohibit the development of corona discharge and equalize the electrical charge generated between two layers. Furthermore, it would have been obvious to utilize the teachings of Grant and to have provided a spring member between the conductor(s) and/or the conductors and the stator slots of Shildneck since such a modification according to column 1, lines 36-49 of Grant would prevent the conductors cable from movement reducing stress in the internal conductor.

The assertion that the high voltage cable taught by Elton could be used as a winding in the machine of Shildneck does not suggest a desirability to use a high-voltage cable as a winding in a rotating electric machine, as claimed. A desirability to modify the reference is required to satisfy the first prong of a *prima facie* case of obviousness. Moreover, the assertion in the Office Action is not supported by any evidence. "The mere fact that references can be combined or modified does not render the resultant combination obvious unless the prior art also suggests the desirability of the combination. *In re Mills*, 916 F.2d 680, 16 USPQ2d 1430 (Fed. Cir. 1990)."[1]

The machine in Shildneck operates at low-voltage, and high-current,[2] where partial discharge does not pose a problem and the insulation system is able to operate at high-temperatures due to the high current.[3] Accordingly, there would be no desire to replace the cable used in Shildneck with a high-voltage cable, such as the one described in Elton.

The machine described in Shildneck was developed in an attempt to provide a cost-effective alternative to conventional coils or bar-type windings in low voltage machines.[4] Mr. Fenton had the unique opportunity to confirm based on first-hand knowledge that the only objective of the team developing the machine in Shildneck was to achieve cost reductions at standard voltages.[5] Therefore, it is understandable that Shildneck does not include any indication of the desirability of increasing the voltage and to use a high-voltage cable, as claimed.[6]

There are features inherent in the Shildneck machine that limits its applicability to low-voltage operation. For example, the outermost layer of the winding is an insulator with no means for creating a uniform potential around the winding or means for field control in the

[1] MPEP § 2143.01.
[2] See declaration of Robert Fenton, at paragraph 40.
[3] *Id.*, at paragraph 40.
[4] *Id.*, at paragraph 40.
[5] *Id.*, at paragraph 40.

end winding region. This configuration is not scalable with regard to voltage and is not descriptive of the claimed high-voltage cable. Use of this machine at higher voltages will result in the breakdown of the insulation material, and ultimately, failure of the machine.[7]

The discussion above provides substantial evidence that there is no desire to modify the machine of Shildneck, or to combine it with a high-voltage cable to arrive at a high-voltage machine. Indeed, such a modification or combination is contrary to the confirmed objectives of the team that developed the machine in Shildneck.[8] Moreover, substantial evidence is provided above that indicates that such a modification or combination to achieve a high-voltage machine is inherently prevented by the configuration of the Shildneck machine.

Thus, the modification asserted by the Examiner would result in a machine that would not be operable as a high-voltage machine, nor would it further the objectives of the machine in Shildneck (i.e., achieving a cost effective alternative to bar-type windings at conventional low voltages) since using the cable shown in Elton would be presumably be more expensive than the cable used in Shildneck. When the "proposed modification would render the prior art invention being modified unsatisfactory for its intended purpose, then there is no suggestion or motivation to make the proposed modification. *In re Gordon*, 733 F.2d 900, 221 USPQ 1125 (Fed. Cir. 1984)."[9]

Consequently, it is respectfully submitted that the burden to establish the first prong of a *prima facie* case of obviousness, that there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings, has not been met by the Examiner.

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[6] *Id.*, at paragraph 41.
[7] *Id.*, at paragraph 41.
[8] *Id.*, at paragraph 40.
[9] MPEP § 2143.01.

The second prong of a *prima facie* case of obviousness requires that there be a reasonable expectation of success in modifying or combining the asserted reference(s). Moreover, the expectation of success must be found in the references themselves or known, but not gleaned from the applicant's disclosure. As discussed above, the combination asserted by the Examiner would not be successful.[10] Accordingly, since combining the machine of Shildneck with the high-voltage cable of Elton will not transform a machine designed to operate at conventional low voltages into a machine capable of operating at the voltages of the present invention, it cannot be said that the Shildneck and Elton references themselves include a suggestion that such a combination would be successful.

The declaration of Mr. Fenton provides substantial evidence that the asserted combination would not result in a machine that could be successfully operated as a high-voltage machine. On the other hand, the Examiner has not provided any evidence to support the assertion that merely replacing the winding in Shildneck with a high-voltage cable as shown in Elton would be reasonably successful in transforming the operational capabilities of the Shildneck machine. Furthermore, as discussed above, there is no reasonable expectation of being able to wind Elton's cable, which becomes stiff when cured, through the stator slots in Shildneck's stator.

Neither Shildneck nor Elton teach or suggest that a combination such as that suggested by the Examiner would be successful. Accordingly, it is respectfully submitted that the assertion that the combination proposed by the Examiner is the product of improper hindsight reasoning made in light of the present application.

Consequently, it is respectfully submitted that the burden to establish the second prong of a *prima facie* case of obviousness, that there must be some suggestion, either in the references themselves or in the knowledge generally available to one of ordinary skill in the

[10] See declaration of Robert Fenton, at paragraph 42.

art, that the asserted combination or modification would be successful, has not been met by the Examiner.

The outstanding Office Action rejects the pending claims by combining Shildneck with both Elton, and Wood. Some of the claims are rejected based on a combination of Shildneck, Elton, and Wood in addition to a fourth reference (i.e., one of Mazzorana, Grant, Siemens, or Madson). However, none of these references cure what is missing in the Shildneck and Elton references required to establish a *prima facie* case of obviousness. There is nothing in any of these references that would facilitate their combination with the machine in Shildneck and the cable in Elton to arrive at the present invention.

It is therefore respectfully submitted that the Examiner has failed to establish any of the three prongs of a *prima facie* case of obviousness, all of which are required. Nevertheless, to the extent that a *prima facie* case of obviousness has been established, Applicants have provided substantial objective evidence of non-obviousness based on secondary considerations. "Objective evidence or secondary considerations such as unexpected results, commercial success, long-felt need, failure of others, copying by others, licensing, and skepticism of experts are relevant to the issue of obviousness and must be considered in every case in which they are present."[11]

The invention of the present application has been commercialized by ABB in the Powerformer™ product, which is an inventive generator that uses the claimed conductor as a winding in the stator.[12] The declaration of Mr. Hirt provides substantial objective evidence as to the commercial success of the Powerformer™ technology, that success being a result of the capabilities of the Powerformer™. The capabilities of the Powerformer™ are due in large part to the inventive use of the particular conductor as a winding.[13] Accordingly, it is respectfully submitted that the nexus requirement between the evidence provided in the

[11] MPEP § 2141.
[12] See declaration of Robert L. Hirt at paragraph 3.

declarations filed herewith and the claimed invention is satisfied, thereby making the evidence of probative value in determining that the invention is nonobvious.[14]

Evidence included in Mr. Hirt's declaration includes evidence of commercial success in licensing the Powerformer technology[15] and evidence of unexpected results.[16] The declaration of Mr. Fenton includes evidence of failure of others[17] and evidence of skepticism of experts.[18] Accordingly, it is respectfully submitted that there is substantial objective evidence and secondary considerations establishing the non-obviousness of the present invention.

Consequently, in view of the present amendment, the declarations filed herewith, and in light of the foregoing comments, it is respectfully submitted that the invention defined by Claims 18-36, as amended, is definite and patentably distinguishing over the asserted prior art. The present application is therefore believed to be in condition for formal allowance and an early and favorable reconsideration of this application is therefore requested.

Respectfully submitted,

OBLON, SPIVAK, McCLELLAND,
MAIER & NEUSTADT, P.C.

Bradley D. Lytle
Registration No. 40,073
Thomas J. Fisher
Registration No. 44,681

Tel. No. (703) 413-3000
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BDL/TJF:

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[13] *Id.*, at paragraph 7.
[14] See MPEP §716.01(b) discussing the nexus requirement and evidence of nonobviousness.
[15] See Hirt at paragraph 4.
[16] See Hirt at paragraphs 10 and 19.
[17] See Fenton at paragraphs 9-11.
[18] See Fenton at paragraph 12.

9847-0001-6X PCT
ENKEL 8025

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF:	:
MATS LEIJON ET AL	: GROUP ART UNIT: 2834
SERIAL NO.: 09/147,325	:
FILED: FEBRUARY 17, 1999	: EXAMINER: ENAD, E.
FOR: ROTATING ELECTRICAL MACHINE COMPRISING HIGH-VOLTAGE STATOR WINDING AND ELONGATED SUPPORT DEVICES SUPPORTING THE WINDING AND METHOD FOR MANUFACTURING SUCH MACHINE	:

DECLARATION UNDER 37 C.F.R. §1.132

ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, D.C. 20231

SIR:

I Robert L. Hirt hereby declare:

1. I am the ABB Group Patent Manager in the Americas for ABB where my address is ABB Power T&D Company, Inc., 1021 Main Campus Drive, Raleigh, North Carolina, 27606. I have over thirty years of relevant experience in the electric power business. My responsibilities within ABB are to manage a portion of ABB's North American patent portfolio.

2. In preparing this Declaration, I have read and considered at least the following documents pertaining to the above-identified patent application: (1) the patent application (U.S. Serial

No. 09/147,325); (2) the Preliminary Amendment filed November 27, 1998; (3) the Office Action dated September 29, 2000; and (4) the Amendment filed on March 29, 2001.

3. Identified herein are several documents that in my view are relevant in demonstrating the recognition by members of the power industry of the significance of the technology embodied by the Powerformer™ which is a commercial embodiment of the presently claimed invention. Powerformer is a trade name developed by ABB identifying a rotating electric machine (e.g., a generator) that uses a high-voltage cable for a stator winding, as covered by the claims in the present invention.

4. Attached as Appendix 1 is a press release dated May 11, 2000, indicating that ABB has been successful in licensing the Powerformer technology to one of ABB's primary competitors, namely, ALSTOM Power. As indicated in this press release, ABB had originally formed a joint business with ALSTOM under the name ABB ALSTOM POWER, but, on or about May 11, 2000, ABB sold its interest in this venture to ALSTOM. Thus, ALSTOM is now the owner of virtually all of ABB's power generation technology and production capability, although ABB retained its ownership of the Powerformer technology.

5. ALSTOM is a competitor of ABB and retained a license to "use this technology in electricity generation as applied in the power generation area." The license agreement to ALSTOM covers the technology of the present patent application, and so ALSTOM has retained a legal right from ABB to commercialize the technology covered by the present patent application.

6. Attached as Appendix 2 is the June 2000 issue of "HIGH VOLTAGE" magazine published by ALSTOM Power. This issue highlights the Powerformer technology and illustrates the impact that it has had on the industry. Several of the articles note the reaction by various industry members regarding how the Powerformer technology, and more specifically, how the use of this particular high-voltage cable as a stator winding in a rotating electric machine

has shocked the rest of the industry, thereby forcing the industry to provide some sort of response. As an example, on page 10 of the magazine, Alain Lacaze discusses the impact ABB's introduction of the Powerformer technology had on ALSTOM (an ABB competitor in this field) in the article entitled "How should ALSTOM meet the 'threat' from Powerformer?" Mr. Lacaze explains that "[w]hen ABB launched the high-voltage generator Powerformer in the spring of 1998 it hit the competitor ALSTOM in Paris like a bombshell. Nobody knew what the new technology would mean for the power generation industry, and a large number of people at ALSTOM started to analyze the situation and investigate alternative action plans."

7. The Powerformer technology, which as reflected in the pending claims, uses a high-voltage cable as a stator winding of a rotating electric machine, is a radical design. It has forced our competitors, such as ALSTOM, to seek different ways of providing a similar product, or perhaps a competing product, so as to remain competitive in this market. The Powerformer technology is a substantially different technology, one facet of which is that high-voltage cables are not used in conventional generators. Accordingly, rotating electric machine engineers are not familiar with such cables. Mr. Lacaze explains this when he states that "[i]t was a particularly difficult situation, as *we weren't experts in the field of high-voltage cables and were therefore obliged to obtain outside assistance to get answers to many of our questions.*" Emphasis added.

8. At page 8 of the same magazine (see Appendix 2), another article entitled "The environmentally friendly generator at Porsi" explains how the design of the Powerformer structure is substantially different than conventional generators because "[t]he [high-voltage] cable is running in long loops. First up, then down like stitches in a complicated piece of embroidery." Mr. Stefan Alfredson, a design engineer for ALSTOM Power the company

that has produced the scheme for how to implement the different stator winding, states in the article that "*[u]sing high-voltage cable in a generator is something absolutely new*, and is therefore very interesting and exciting to get the opportunity to participate in this project." Emphasis added.

9. In the same magazine (see Appendix 2), it is further explained what has also been ABB's experience - that a number of different industry members have been extremely curious as to the structure and operation of the Powerformer-type device. For example, in the article entitled "It's running like clock work," at pages 4-5, it is explained that

> "ever since the start-up of Powerformer, quite a number of visitors from around the world have passed by. From China, Japan, Iceland, various African countries, Vietnam, Thailand and the U.K.. Just to mention a few of them. And they all share one thing in common. 'When they see Powerformer, they look [sic] the pictures of bewilderment, they have never seen anything like this before,' says Kalle Nilsson."

   Mr. Nilsson is employed by Vattenfall Kraft- och Industriservice AB, which has recently purchased a Powerformer generator that implements the claimed invention. Mr. Kalle Nilsson also explains in this article that "[v]isitors from different continents are still pouring into our small village. This indicates that Powerformer will continue to raise great interest also in the future."

10. Attached as Appendix 3 is the July/August 2000 edition of "International Turbomachinery" magazine, which includes an article entitled "Powerformer goes horizontal at Eskilstuna" explaining part of the reason why people consider the Powerformer to be so different. The article explains that "[f]or more than 100 years the design of an electric generator has remained basically the same. . . . but always the generator was a high current, low voltage device. A typical generator output voltage is between 10 and 25 kV." The article then goes on to explain that improvements to high-voltage insulation were worked on by high-voltage cable manufacturers, which were "outside the power generation business." Furthermore, the

high-voltage cable manufacturers were never partners with contractors in building power plants, but rather had separate contracts. As a consequence, the Powerformer is generally believed by the industry to be a radically different design because the present inventors recognized that using the high-voltage cable having the structure reflected in the pending claims, in a stator of a rotating electric machine, offers enormous benefits not previously appreciated. As explained in the article, "although the Powerformer rotor is similar to that of a conventional generator with brushless excitation, *the assembly of the stator is significantly different*. The stator frame is stood on end and the winding is built up from continuous 300 metre lengths of XLPE insulated cable. The cable is drawn up a slot and at the top of the frame is passed down the diametrically opposite slot. Almost the entire length of 300 m is drawn through the first slot. Thereafter the cable is passed up and down to create the turns." Emphasis added.

11. The article continues to explain that the Powerformer has an unusual design in the end winding region as well. The article properly explains that "there is no potential difference between the winding surface and the stator body or between adjacent coils." Furthermore, the article explains that "[s]ince the winding is at a higher voltage the current is substantially lower. In the [Powerformer] machine for Eskilstuna the stator current is about 170 A whereas in a conventional low voltage generator of the same rating, the current would be nearly to 2000 A."

12. Another significant feature that should help to explain why the present invention is not based on an obvious combination of a high-voltage cable with the stator of a conventional machine is that ALSTOM, ABB's competitor and licensee of the Powerformer technology, has been successful in selling Powerformer generators in industry. As explained in ALSTOM's June 22, 2000 press release entitled "ALSTOM Power receives major order to supply fourth

Powerformer™ for the Höljebro Power Plant in Sweden," (attached hereto as Appendix 4) a "high-voltage cable is used in Powerformer instead of the square [or rectangular] insulated copper conductors to be found in a conventional generator. Due to the cable, among other things, Powerformer can produce voltages up to 400 kV." The first Powerformer was introduced in the Porjus Hydro Power Plant in June 1998. This power plant is owned by the Porjus Foundation whose members include Vattenfall Vattenkraft AB, ALSTOM Power Västerås, and GE Energy AB, which represents a fairly significant cross-section of power generation suppliers. A second Powerformer at Porsi Hyrdopower Plant will be commissioned in the spring of 2001. Eskilstuna Energi and Miljö ordered the first Powerformer for thermal power in 1998, and it will be inaugurated in 2001. This June 22, 2000 press release explains that ALSTOM also received a new order to supply a high-voltage Powerformer to the Swedish Utility Company Fortum Kraft AB which is responsible for producing electricity in about 40 hydropower plants in central Sweden. As explained by the Production Manager for the customer of this Powerformer, "Powerformer represents a significant step forwards [sic] in technology development. After a century with conventional technology, we have been eagerly awaiting a high-voltage generator like this."

13. Attached hereto as Appendix 5 is another press release from ALSTOM identifying that "Powerformer™ sets new world record." As explained in this press release, the Powerformer generator in the Eskilstuna Combined Heat and Power Plant in Sweden "has successfully operated at 136 kV during running tests and that 177 kV during overexcitation test. This is a world record in generator terminal voltage." Also explained in this press release is that this level of operation is far different than conventional generators which have rated voltages on the order 10 kV. A direct result of the Powerformer design is a recognized new world record for high-voltage operating machines in commercial environments.

14. Attached hereto as Appendix 6 is the cover from the April 2000 edition of "Electra" magazine published by Cigre' which contains a photograph showing the stator windings of a Powerformer generator. The fact that an industry organization such as Cigre' would select such a photograph for the cover of its publication indicates to me that the Powerformer design, which uses high-voltage cable as a winding of a stator of a rotating electric machine, as reflected in the pending claims, would be considered as new and interesting to those in the industry. The high-voltage cable winding configuration of the Powerformer, is different enough from conventional generators that it was made to be the subject of a cover photograph on an industry periodical that doesn't even contain a caption. This indicates to me that using a high-voltage cable as a stator winding in a generator is, by itself, newsworthy, and thus not obvious to the targeted audience of the periodical (i.e., members of the power industry).

15. I further state that all statements made herein to my own knowledge are true and that all statements made herein on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both under Section 1001 of Title 18 of the United States Code and that such any willful false statements may jeopardize the validity of the application or any registration resulting therefrom.

Robert L. Hirt

Robert L. Hirt

3-30-01

Date

APPENDIX 1

Press Release, May 11, 2000:

"ABB's sale of share in ABB ALSTOM POWER concluded"

BW1599 MAY 11,2000 10:58 PACIFIC 13:58 EASTERN

(BW)(ABB-GROUP) ABB's sale of share in ABB ALSTOM POWER concluded

Business Editors

ZURICH, Switzerland--(BUSINESS WIRE)--May 11, 2000--ABB said today it has concluded the sale of its 50-percent share in ABB ALSTOM POWER to ALSTOM, another milestone in the global technology company's transformation to a knowledge and service-based business.

"To be a leader by combining the classical economy with the new economy, we are increasing the share of our business in service, IT, eBusiness and other high-tech and knowledge-based activities," said ABB President and CEO Goran Lindahl. "We are growing in businesses and business combinations where we can be market leaders and gain significantly higher margins."

ABB and ALSTOM merged most of their respective power generation activities to create the joint 50-50 company in June 1999. After obtaining regulatory approvals for the divestment of its 50 percent to ALSTOM, ABB today received a cash payment reflecting the valuation of its share as well as outstanding issues between ABB and ALSTOM.

ABB keeps full ownership of the so-called Powerformer technology which is now being applied in several ABB products and systems. ALSTOM retains a license to use this technology in electricity generation as applied in the power generation area.

Earlier this month, ABB finalized the sale of its nuclear activities to BNFL of the U.K.

ABB will in the future be present in distributed power, with technologies like microturbines, and all renewables, such as fuel cells and wind power (but not including hydro power). Small-scale applications of combined heat and power are a particular focus of ABB. The company will present its strategy for these alternative energy technologies, including novel wind farm solutions, in London on June 8 (www.abb.com/newenergy).

In addition, ABB reiterates its forecast for 2000 of increased orders and revenues as well as operating earnings compared to 1999, excluding the extraordinary gain of US$262 million. The longer-term target of 12 percent result margin for the ABB Group by 2003 is not negatively affected by the divestments to ALSTOM and BNFL.

The ABB Group (www.abb.com) serves customers in power transmission and distribution; automation; oil, gas, and petrochemicals; building technologies; and in financial services. With novel IT applications, tailored software solutions, growing eBusiness and a fast-expanding knowledge and service base, ABB is building links to the new economy. The ABB Group employs about 165,000 people in more than 100 countries.

--30--ac/ny*

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KEYWORD: INTERNATIONAL EUROPE
INDUSTRY KEYWORD: OIL/GAS COMPUTERS/ELECTRONICS SOFTWARE

APPENDIX 2

"HIGH VOLTAGE"
June 2000

HIGH VOLTAGE

THE STORY BEHIND THE HIGH-VOLTAGE GENERATOR FROM ALSTOM POWER. JUNE 2000

This is ALSTOM Power

ALSTOM Power is a world leader in the supply of power generation equipment and services, with a presence in more than 100 countries. The Group offers its customers a comprehensive capability, which ranges from the supply of components to turnkey power plants and financial services.

ALSTOM Power comprises eight business segments. Its product range includes turnkey plants, gas turbines, steam turbines, hydro turbines, generators, boilers, heat exchangers, control systems, environmental systems, customer service and project finance.

The company's head office is situated in Brussels, Belgium. Pro forma revenues for 1999 totalled €10 billion.

Powerformer™ – the high-voltage generator

Powerformer is the trademark for a rotating electrical machine with high-voltage cables in the stator winding. ABB made the invention and owns the basic patents.

In the agreement between ABB and ALSTOM, ALSTOM Power has been given the exclusive right to exploit this new technology for all generator types and applications. The agreement also includes an exclusivity clause. This means that in this field it is ALSTOM Power that develops, sells, engineers, manufactures and services Powerformer.

The sales organizations for hydro and thermal Powerformer applications are already defined and functioning within ALSTOM Power. Powerformer is considered a fully commercial product based on proven technology.

The development project, which has already been focused for some time on product development, is being run as one of the major development projects by and within ALSTOM Power. The company is committed to a rapid volume growth for both hydro and turbogenerator applications.

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Magnus Jonasson, President of ABB ALSTOM POWER Generation and the customer Sven Andersson, Production Manager at StoraEnso Energy.
PHOTO: LASSE FREDRIKSSON

contents

Keeping our customers competitive

When Powerformer was launched in 1998, I recall that we at ALSTOM spent considerable resources on assessing the implications of this revolutionary technology for the market. I am very happy now to have Powerformer in the rich product portfolio of ALSTOM Power.

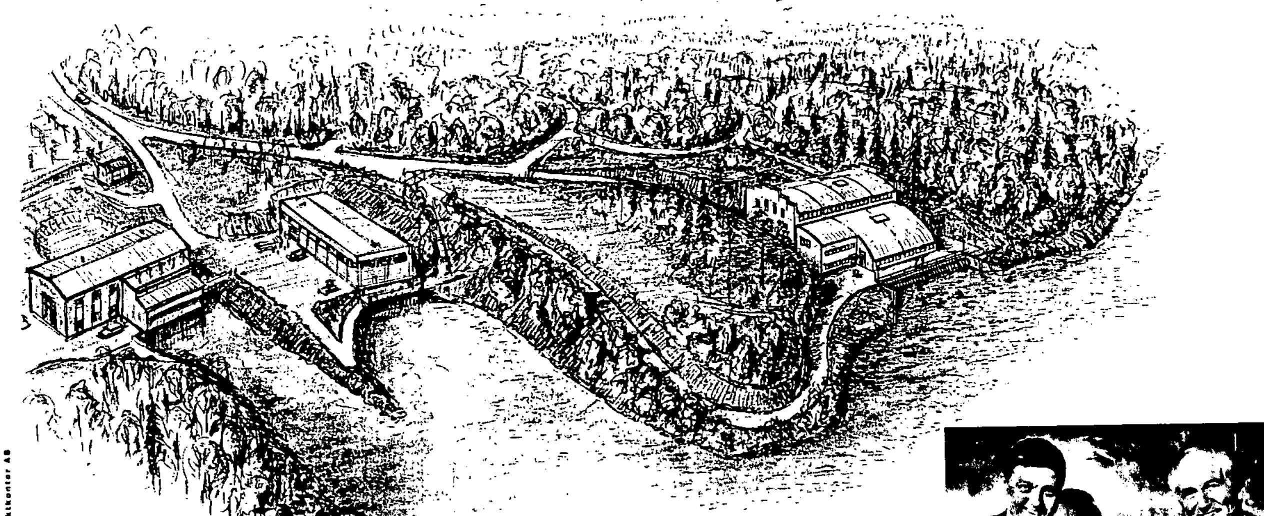
When we set up ABB ALSTOM Power, we came on the scene as the largest company in the world's power generation sector - a market leader from the very outset. That is all very fine, but what does it take to foster and keep this position? Everything we set out to do aims at offering our customers added value – keeping our customers competitive. A very important factor in this respect is to maintain the technical lead.

The new high-voltage generator Powerformer is a typical example of an innovative system concept that offers added value to our customers. It combines higher efficiency, simplicity and a reduced environmental impact – qualities that are playing an increasingly important role in the power generation market.

New technologies are often, and sometimes rightfully so, received with cautiousness and also a bit of scepticism. However, we have now logged some 10,000 operating hours with Powerformer and we have performed extensive tests to really challenge the concept. And it still runs like clockwork. Everything points to the fact that Powerformer is now a fully commercial product and that it will play an important role in the future success of the new ALSTOM Power group.

BERNARD LEMOINE
Managing Director,
Steam Power Plant Segment
ALSTOM Power

World's fourth Powerformer for Höljebro Hydropower Plant



Ill: Klas Holmgren arkitektkontor AB

ALSTOM Power has received yet another order for the high-voltage generator Powerformer. This is the world's fourth Powerformer.

Photo: Lasse Fredriksson

"It is very gratifying for us that StoraEnso Energy has chosen tomorrow's technology for the production of electricity," says Magnus Jonasson, President of ABB ALSTOM POWER Generation AB, Västerås. To the right, the satisfied customer Sven Andersson, StoraEnso Energy.

Technical data

Output
25 MVA

Voltage
78 kV

Speed
115.4 r/min

Frequency
50 Hz

The customer is the Swedish utility Stora-Enso Energy AB, which produces electricity in around 40 hydropower plants in central Sweden. The high-voltage generator Powerformer, with its unique capability to generate high voltage for feeding direct to the transmission network without the need for a step-up transformer, will be installed in Höljebro Hydropower Plant, located on the Ljusnan river, just south of the town of Söderhamn.

Powerformer will replace the two oldest units from the 1930s in the power plant and will be connected direct to the 70 kV network. The new generator will be installed in an extension to the existing powerhouse. The upgraded power plant is scheduled to enter into operation in June 2001.

Photo: Lasse Fredriksson

"We have been eagerly awaiting this high-voltage generator," says Sven Andersson, left, Production Manager at Stora Enso Energy. Recently he got together with his colleague Lennart Henriksson as well as Henrik Lundström and Gunnar Karlefur, both from ALSTOM Power, during the signing of the Powerformer contract for Höljebro Hydropower Plant.

A significant step forwards

"Powerformer represents a significant step forwards in technology development. After a century with conventional technology, we have been eagerly awaiting this high-voltage generator. And what makes the situation still better is that the environmental benefits are so tangible, such as the absence of a step-up transformer," comments Sven Andersson, Production Manager at StoraEnso Energy.

"It is very gratifying for us that Stora-Enso Energy has chosen tomorrow's technology for the production of electricity," says Magnus Jonasson, President of ABB ALSTOM POWER Generation AB, Västerås.

Increased market shares

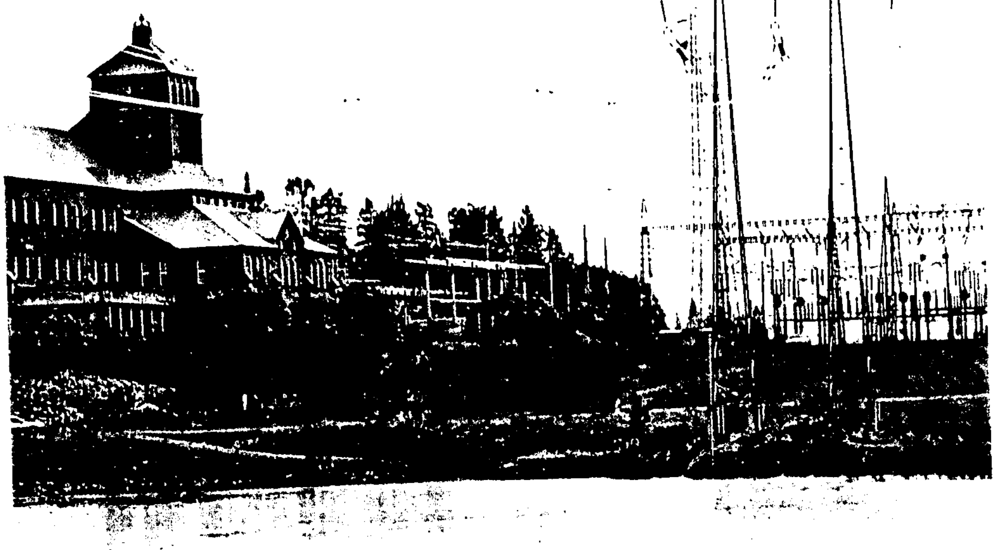
"The Höljebro installation will give us good opportunities to increase our market shares, both nationally and internationally. Powerformer having the same output as the Höljebro machine can really become 'best sellers' in the future, not least against the background that many conventional generators in, for example, Sweden must be refurbished in the future.

Lower energy losses

Comparative Life Cycle Assessments of Powerformer and conventional generator technology show that reducing the size of the power plant and the number of components will also lower the maintenance costs and the energy losses. Installing Powerformer in Höljebro together with the environmental benefits of the high-voltage cable technology applied in the generator will over thirty years give an value equivalent to approximately € 1.8 million.

"It's running like c

Realistic testing of an 11 MVA Powerformer generator under abnormal conditions and its interaction with the transmission network. This sentence summarizes to some extent what is going on in the old Porjus Power Plant on the Lule river.



Power with Powerformer at Porjus

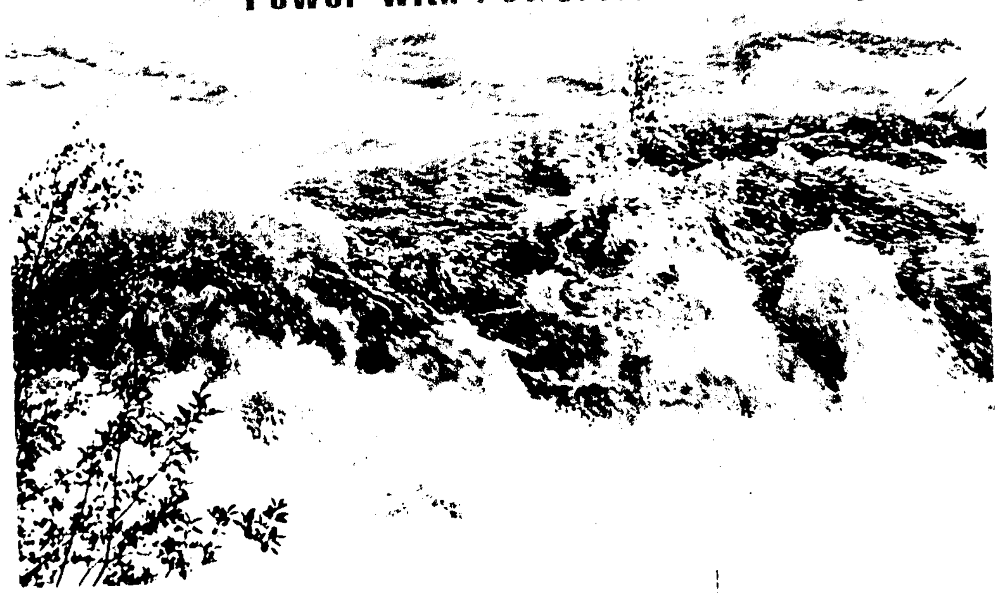


Photo: Kalle Nilsson

Karl Olof "Kalle" Nilsson is employed by Vattenfall Kraft- och Industriservice AB. He is working in the power plant and one of his jobs is to look after ALSTOM Power's new high-voltage generator on behalf of the Porjus Hydro Power Centre.

Have there been any problems, Kalle?

"No, it is now a little boring. Powerformer is running like clockwork," he says and laughs.

In the small community of Porjus with 472 inhabitants in northern Sweden the high-voltage generator Powerformer is undergoing a series of tough tests. It is not enough just to evaluate the generator by means of comprehensive factory tests and tests in a number of test rigs. Realistic tests are naturally preferable. Since the start of the testing at Porjus in the summer of 1998, Powerformer has been generating power without any interruptions caused by the Powerformer generator itself. On the other hand, the network has occasionally tripped the generator due to external contingencies.

Training and development centre

The old Porjus Power Plant is not just any hydropower plant. In fact, it includes a training and development centre, the Porjus Hydro Power Centre, for internationally advanced hydropower technology. Two leading manufacturers and a power producer lie behind the Centre: Vattenfall Vattenkraft AB, ABB ALSTOM POWER Generation AB and GE Energi AB.

And what is then more natural that one of the generators in the Centre is a Powerformer machine, which represents tomorrow's technology.

"Apart from the fact that Powerformer is running like clockwork, it is undeniably fascinating that it operates so silently as it does, you can hardly hear it when you are in the generator hall," says Kalle Nilsson. Since the start-up the generator has been running (at the time of writing) for more than 8,000 hours, delivering full power into the network.

Ever since the start-up of Powerformer, quite a number of visitors from around the world have passed by. From China, Japan, Iceland, various African countries, Vietnam, Thailand and the UK. Just to mention a few of them. And they all share one thing in common.

"When they see Powerformer, they look the pictures of bewilderment, they have never seen anything like this before."

ockwork"

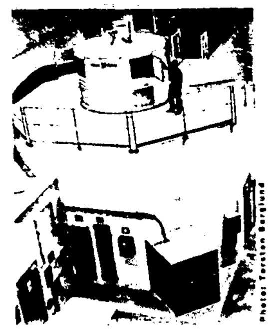


Photo: Torsten Berglund

says Kalle Nilsson. "It's an 'aha' experience for all of them and they are all fascinated by the new environmentally friendly technology, the lower energy losses and the connection of the machine direct to the transmission grid without any step-up transformer."

Fewer parts than a conventional machine

Powerformer technology also has other major benefits. The high-voltage generator, i.e., without any step-up transformer, in general has a smaller footprint and fewer parts than a conventional system. One example is that a standard high-voltage circuit-breaker is used as the generator breaker. This, too, is an 'aha' experience for most people.

The full-scale testing of Powerformer has been and still is being conducted under realistic conditions. It is naturally fully possible to test the generator in the factory at home, but only to a limited extent. Factory tests can only be used to determine efficiencies, vibrations, noise and temperature rise. At Porjus it is possible to test the complete system concept, that is not only the generator itself, but also the turbine and the governing and control equipment for the unit.

It is important to study Powerformer and its interaction with the transmission network. All the system impacts that the engineers can want occur at Porjus, namely a 400 kV line close to a 45 kV line and two large generators close by. The system engineering validation is important for the design criteria used for Powerformer. Thanks to this concept, the engineers can obtain an overall view of the complete energy system. This overall approach can be verified on the network by means of tests.

In operation for more than 8,000 hours

As already mentioned, the Powerformer generator at Porjus has now been in operation for more than 8,000 hours. When the generator has been in service, it has mostly been run at full power, namely 9.5 MW. The mean value of the voltage has been 44.5 kV. The normal value for a conventional hydropower generator is 10 to 25 kV.

The design engineers know that Powerformer is functioning well. Howerve they do not rest on their laurels, but are looking for exact measurements of, in principle, everything. And it is here that Dr. Stefan Johansson, a researcher from ABB Corporate Research in Västerås, comes into the picture. He has visited Porjus on several occasions to perform tests on generator unit U9, as Powerformer is called at Porjus.

"We have really gone the whole hog," says Stefan Johansson. "Conventional generators do not normally have to undergo such severe tests as those performed on Powerformer U9. And all I can say is that the concept stands up to them! Nothing strange – not a single thing – that we have been unable to predict or explain has occurred during our tests. And even so we have subjected Powerformer to some of the most difficult faults that can affect a generator."

Field measurements on U9

Stefan Johansson started to work at ABB Corporate Research just over a year ago. Since then he has devoted many weeks to field measurements on U9 at Porjus. And actually, literally speaking, he has frequently been standing up to his waist in snow in order to carry out his tasks. When it snows at Porjus, then there is really a lot of snow!

"It's quite natural that we must be more precise with our testing and the tough running of such a new product as Powerformer," states Stefan Johansson. "A conventional generator in all likelihood doesn't have to be exposed to, for example, such numerous short-circuit tests as those we performed on Powerformer U9.

"It took a whole week to perform the short-circuit tests. We first carried out a series of tests with a three-phase short circuit on U9's terminals at different voltages. The 10-s-long short circuit from full voltage merely sounded like a quiet, muffled rumble and it all felt undramatic," continues Stefan. "We also performed two- and single-phase tests. Single-phase no-load short circuits are something a little special, because they subject two healthy phases of a generator to extra-high voltage stresses.

Powerformer has also undergone load shedding under load, harmonic measurements, and acoustic measurements and simulated low-amplitude lightning overvoltages. Measurements on the auxiliary winding in the machine have been of particular interest. This winding has a rating of 750 V, 110 kVA and feeds the generator's own equipment.

"Only a few generators have been built with double windings in the stator, but they are then generally symmetrical. We have one large and one small winding in the stator, which makes the modelling and calculations more interesting," says Stefan. "A lot of analytical work now remains to be done, since we'll be using all the results to learn how to predict quantitatively the way in which future Powerformer generators will behave already at the calculation stage."

Powerformer continues to raise great interest

At the time of writing, Stefan Johansson is fully occupied in performing further tests at Porjus. And what about Kalle Nilsson?

"Visitors from different continents are still pouring into our small village. This indicates that Powerformer will continue to raise great interest also in the future. I hope that many people will now apply the new technology so that in five to ten years' time we'll see at least ten high-voltage generators in Sweden," concludes Kalle Nilsson.

Output
11 MVA

Voltage
45 kV

Speed
600 r/min

Frequency
50 Hz

Photo: Stefan Johansson

"Apart from the fact that Powerformer is running like clockwork, it is undeniably fascinating that it operates so silently as it does, you can hardly hear it when you are in the generator hal" says Karl Olof "Kalle" Nilsson, who is employed by Vattenfall Kraft- och Industriservice.

Photo: Kalle Nilsson

"Nothing strange – not a single thing – that we have been unable to predict or explain has occurred during our tests," says Dr. Stefan Johansson from ABB Corporate Research, Västerås.

The most efficient tu

October 8, 1998. A red-letter day. This was the day when the contract for the world's first Powerformer for commercial operation was signed. The order received by ALSTOM Power was valued at approximately € 10 million. It also included the steam turbine and other electrical equipment.

Technical data

Output	**42 MVA**
Voltage	**136 kV**
Frequency	**50 Hz**
Speed	**3,000 r/min**

Photo: Tomas Forssander

"Because our scope of delivery is large, we are responsible for the complete system undertakings, which benefits both parties," says Jan Nordlund, Project Manager at ALSTOM Power and in charge of the delivery to Eskilstuna.

The customer, the municipal utility Eskilstuna Energi & Miljö AB, was naturally very positive at that time. And they are certainly of the same opinion today.

"By using Powerformer we'll get the cheapest and most environmentally friendly electrical power," says Lars Andersson, President of Eskilstuna Energi & Miljö. "We expect that the investment will have a payback time of 7 to 10 years."

The first test unit with the new, revolutionary high-voltage generator Powerformer entered into service at the Porjus Hydro Power Centre in June 1998. Five months later it was decided that a turbogenerator based on the same technology, but adapted to thermal power plants, should get its first reference plant in Eskilstuna, south-west of Stockholm.

Inauguration in March next year

The new CHP plant in Eskilstuna will be inaugurated in March next year. Its fuel will consist of forestry and sawmill waste products, in other words only biomass fuels. The power plant will produce 167 GWh of electricity, 330 GWh of heat and an additional 70 GWh of heat obtained from the condensation of the flue gases.

"We are investing approximately € 54 million in the new CHP plant," says Lars Andersson. "The investment costs for the Powerformer system as such are the same as for a conventional electrical system. However, the Swedish State in the form of the Swedish National Energy Administration is backing this project, by giving us a grant of approximately € 13 million, funding emanating from Sweden's policy to change the country's power generation portfolio from fossil/nuclear fuels to renewables.

Lower maintenance costs

"Due to the higher efficiency, better performance and lower maintenance costs, however, we believe that the environmentally friendly technology with a 42 MVA Powerformer generator in the long term will give a better profitability than a conventional plant," continues Lars Andersson. "I'm convinced that the new energy system will give us as power producers both more efficient operation and lower maintenance costs."

The Powerformer generator in the Eskilstuna CHP plant will be connected direct to an existing 136 kV substation. The power plant will be compact, thanks to fewer components such as step-up transformer, medium-voltage switchgear and other electrical equipment, which will also result in a greater availability. And the losses will be cut by about 400 kW. This reduction of the losses will raise the plant efficiency by one percentage point.

Nearly two years have now passed since ABB Generation, now part of ALSTOM Power received the order from Eskilstuna Energi & Miljö. What has happened since then, Jan Nordlund, Project Manager at ALSTOM Power and in charge of the delivery to Eskilstuna?

"We're not exactly being idle," laughs Jan Nordlund. "Implementing a project of this magnitude is naturally a challenge that is something outside the ordinary. If you

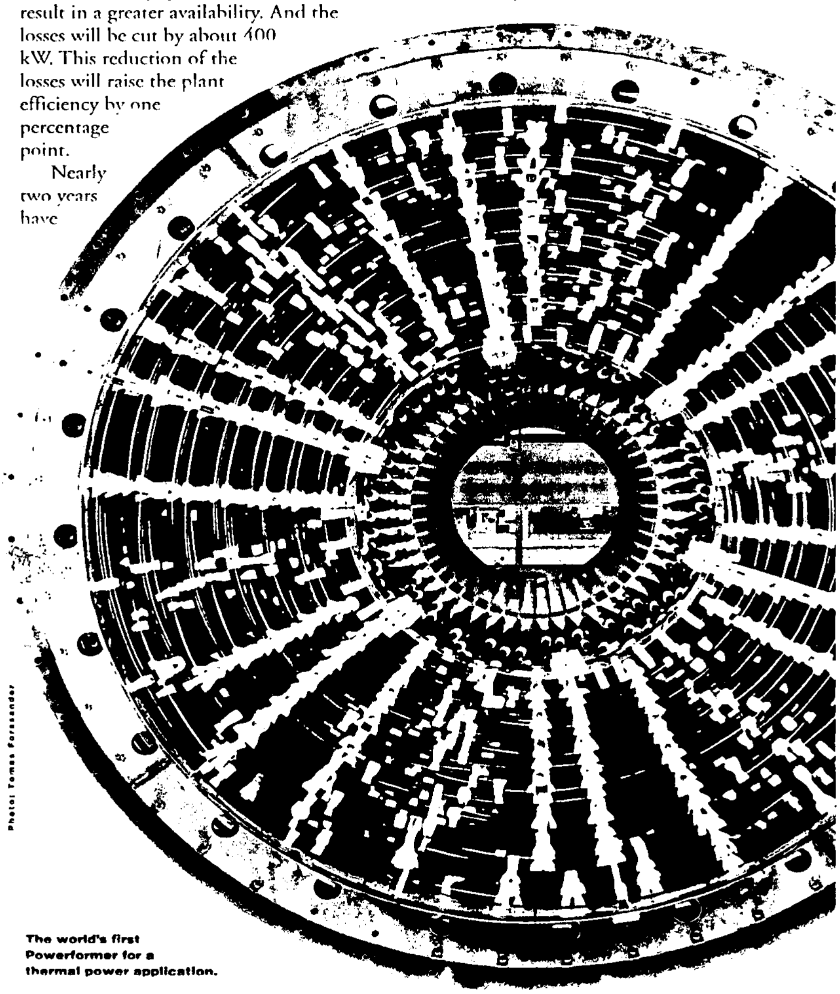


Photo: Tomas Forssander

The world's first Powerformer for a thermal power application.

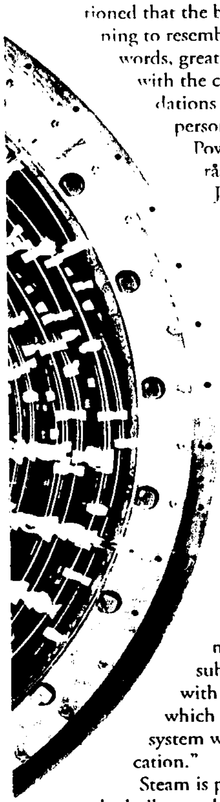
rbogenerator

look around, you will quickly realize that large development programmes tend to drag on. What is unique about this project is that we are undertaking development within the framework of a commercial contract and that we have a customer who wants his plant to enter into commercial operation on an exact date."

Four weeks of rotating type tests

Powerformer will be delivered to the site at the end of June. Prior to this the high-voltage generator has been undergoing a very comprehensive test programme in the factory in Västerås throughout the manufacturing phase. The programme involved, among other things, four weeks of rotating type tests including a 100 per cent short-circuit test. It should be underlined here that no abnormal results at all were obtained during all the tests they have performed.

At the time of writing it can be mentioned that the building site is now beginning to resemble a power plant. In other words, great progress has been made with the civil works. The foundations are finished and erection personnel from ALSTOM Power in Finspong and Västerås are on site. It is in fact Jan Nordlund and his people who have the overall responsibility for the delivery of all the equipment from the turbine coupling on the Powerformer generator to the connection to the existing 136 kV substation 1.3 km away.



Optimize the system

"As our scope of delivery is large, we are responsible for the complete system undertakings, which benefits both parties," points out Jan Nordlund. "The customer reduces his number of subcontracts and we can work with a functional specification, which enables us to optimize the system within the functional specification."

Steam is planned to be available from the boiler on the site in September so that the rotating commissioning can start. Test running will take place in November and the customer will take over the plant in December in good time before the inauguration in March 2001.

This Powerformer is consequently the world's first Powerformer for a thermal power application. How have you been able to benefit from the fact that a Powerformer for a hydropower plant is already in commercial operation?

"The turbogenerator concept is based on the good experience we have had with the Porjus unit," declares Jan Nordlund. "During the conceptual phase, that is up to March 1999, we had several in-depth technology meetings with the customer."

No technical doubts

As technical support the Eskilstuna company engaged the services of experienced specialists at Vattenfall. After the conceptual phase there were no technical doubts on the part of the customer. It was naturally of help to Jan Nordlund and his colleagues that they were able to refer all the time to the excellent experience of Powerformer in the Porjus Hydropower Plant.

"Working in this sector means that you must always respond to the customer's needs," says Jan Nordlund. "No project is exactly identical to other ones. At ALSTOM Power we are in the process of developing a series of Powerformer turbogenerators, which will meet the different requirements of the market in the best possible way. Our customer and we are fully convinced that the turbogenerator concept that has now been developed for Eskilstuna will function.

Opens doors to new exciting markets

"Several customers from all regions in the world are already interested in the Powerformer technology," concludes Jan Nordlund. "The possibility to use the Eskilstuna CHP as a reference plant will open doors to completely new, exciting markets. There is a big market for thermal power plants in Europe and not least in North America."

Footnote
An analysis made by Eskilstuna Energi & Miljö shows that the life-cycle cost of a CHP plant based on Powerformer technology should be 15 per cent lower than for a conventional plant. This analysis took into account the investment costs, earnings, operation and main-

Photo: Eskilstuna Energi & Miljö

"By using Powerformer we'll get the cheapest and most environmentally friendly electrical power," says Lars Andersson, President of Eskilstuna Energi & Miljö (right), here together with Nils-Göran Karlsson, Project Manager for the entire Eskilstuna plant. "We expect that the investment will have a payback time of 7 to 10 years."

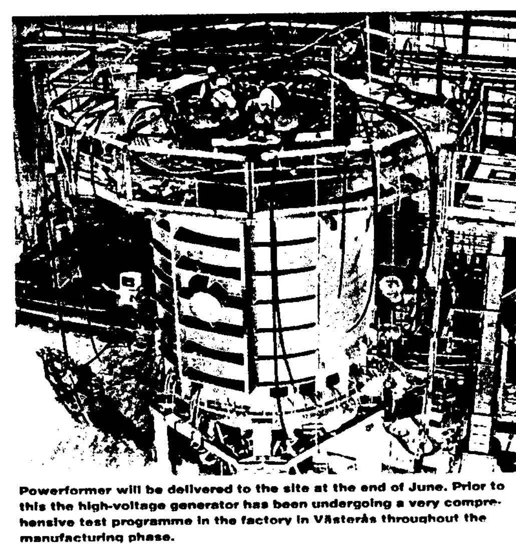


Photo: Tomas Forssander

Powerformer will be delivered to the site at the end of June. Prior to this the high-voltage generator has been undergoing a very comprehensive test programme in the factory in Västerås throughout the manufacturing phase.

The environmentally friendly generator at Porsi

The new generator, a full-scale Powerformer, is now slowly but surely beginning to grow in the machine hall of Porsi Hydropower Plant. Thanks to a number of benefits, this high-voltage generator will be a competitive and environmentally friendly alternative to conventional power plants.

"Yes, it's a really environmentally friendly generator," states Sören Ek, Environmental Manager at Vattenfall's hydropower business.

A lot of work is being done just now in and around Porsi Hydropower Plant, with its attractive site on the Lule river, just outside the small community of Vuollerim in Lapland. The Swedish utility Vattenfall has decided to protect the forest and endangered flora in the Vuollerim ravine close to the power plant and to turn the area into a small nature reserve. This in itself is a radical move by a power utility, but the focus on the environment is not limited just to the exterior.

A new high-voltage generator, a Powerformer unit of commercial size and the first of its kind, is being built inside the power plant. The generator will be able to deliver electricity direct to the transmission network without the need for any step-up transformer. This revolutionary invention not only makes the generation of electricity more efficient, but also has major consequences for the environment around the power plant.

Avoiding many problems

"Yes, it's a really environmentally friendly generator," states Sören Ek, Environmental Manager at Vattenfall's hydropower busines. "Now that we don't need to step up the generator voltage, we can also avoid many of the problems associated with conventional systems. These include the risk of leaking oil. And in this particular case it is not only the step-up transformer that can now be taken away. We are also replacing the Kaplan turbine by a fixed-blade turbine. A Kaplan turbine in fact contains quite a lot of oil and it is therefore very positive that it can also be replaced."

Inside the power plant's large machine hall it looks like as if a lunar module has just landed. A team of men, dressed in blue, are dashing in and out of the high metal structure, which, when examined more closely, proves to be the actual shell of the high-voltage generator. The men from ALSTOM Power have just started the arduous job of winding the stator with power cable. The cable is running in long loops. First up, then down like stitches in a complicated piece of embroidery. No less than 16 km of cable will be installed in this way. In principle, ordinary standard cable is being used.

Output
75 MVA

Voltage
155 kV

Speed
125 r/min

Frequency
50 Hz

"Everything has gone very smoothly," says Stefan Alfredsson, design engineer from ALSTOM Power who has produced the scheme for the complex stator winding. "Using high-voltage cable in a generator is something absolutely new, and it is therefore very interesting and exciting to get the opportunity to participate in this project," he continues.

As far as Vattenfall is concerned, it is important that they now get confirmation that the high-voltage generator works on the levels where the new technology gives the greatest benefits.

"When the generator is ready, it will supply electricity at a voltage of 155 kV direct to the transmission network. And this voltage level is very interesting, because Porsi and many other generators belonging to Vattenfall are connected just to this level," says Kjell Isaksson, who is responsible for Vattenfall's hydropower plants.

Modernization of old generators

The Porsi project will also demonstrate that the technology can be used for the refurbishment of old units. If the new technology proves to function well, it will serve as an alternative in the future modernization of old generators.

"It's all about the refurbishment of units that are now between 40 and 50 years old. The gradual introduction of the new technology over a 30-year period would result in savings of up to € 120 million," believes Kjell Isaksson.

Construction of Porsi Hydropower Plant was completed in 1958. The power plant has an output of about 300 MW and it is connected to the 130 kV grid. The high-voltage generator will replace one of the three existing units.

Power

The newly developed round, XLPE insulated stator winding makes it possible to connect Powerformer direct to the transmission system. This means that Powerformer can replace the conventional generator and the step-up transformer.

The absence of the step-up transformer enables the transmission system to be supported with more reactive power. Alternatively, we can reduce the size of Powerformer and still support the system with the same amount of reactive power as the conventional generator can. Figure 1 shows the capability diagram for a conventional generator with step-up transformer.

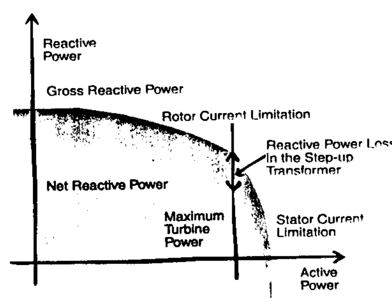


Figure 1. Capability diagram for a conventional generator with step-up transformer.

The horizontal axis of the capability diagram shows the amount of active (real) power that the generator can deliver to the power system. The active power makes our motors rotate as well as lights and heats our homes. The owner of the power plant gets paid for the amount of active power that is delivered to the customer. The vertical axis in the capability diagram shows the amount of reactive power that the generator can deliver to the transmission system. Figure 1 also shows that the reactive power losses in the step-up transformer reduce the amount of reactive power that can be delivered to the transmission network. The reactive power losses may amount to 15 Mvar for a 100 MVA generator.

The reactive power supports the voltage on the transmission system and increases the transfer capability of the power transmission network. An old rule of thumb says that an extra Mvar of reactive power in an area with consumption surplus increases the transfer capability from an area with gener-

ormer supports the grid

WRITTEN BY STURE LINDAHL

Photo: Lasse Fredriksson

Sture Lindahl explains how Powerformer can support the grid.

ation surplus by an extra MW. Sometimes the price of electricity may be €10/MWh higher in the consumption area than in the generation area. Under such conditions the benefit of one extra Mvar of reactive power is € 10/hour. In some of the countries with a deregulated electricity market the owner of the power plants gets paid for various ancillary services such as the delivery of reactive power to the transmission network. In other countries the network owner just requires that the plant owner supplies a certain amount of reactive power to the transmission network.

Let us now consider the benefit of a 100 MVA Powerformer with a power factor of 0.85 in a system where the plant owner gets paid for the delivery of reactive power. We compare Powerformer with a conventional 100 MVA generator with a power factor of 0.85 and a 100 MVA step-up transformer. Powerformer does not need a step-up transformer and $100\sqrt{1-0.85^2}=52.7$ Mvar of reactive power from Powerformer is available for the transmission network, see Figure 2.

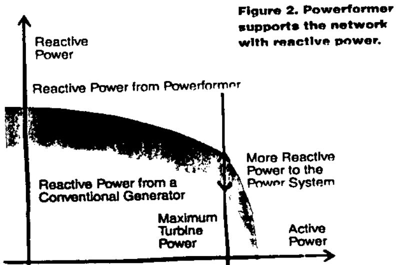


Figure 2. Powerformer supports the network with reactive power.

The conventional generator cannot be connected direct to the transmission network and requires a step-up transformer. The reactive power losses in the step-up transformer are about 15 Mvar and 52.7 – 15 = 37.7 Mvar is available to the transmission network. This means that Powerformer provides the network with 15 Mvar more than the conventional generator does. The benefit of these extra Mvar of reactive power has a value of 15 x 80 = SEK 1,200/hour (€ 150/hour). We assume that the transmission network needs the extra reactive power during 2,000 hours per year. The yearly benefit is then equal to 1,200 x 2,000 = SEK 2,400,000/year or SEK 2.4 million/year (€ 0.3 million/year). We assume that the investment has an economical lifetime of 25 years and the interest rate is 4%. This means that the present-value factor is equal to 15.6 and the present value of the benefit is equal to 15.6 x 2.4 = SEK 37.4 million (€ 4.68 million).

The plant owner does not always get paid for the entire benefit to the transmission network of the extra reactive power. Mechanically switched shunt reactors can sometimes provide the necessary reactive power at an investment cost of about SEK 0.16 million/Mvar (€ 0.02 million / Mvar). In other cases the transmission network may need a continuously variable reactive power source, like a static var compensator (SVC) or a synchronous machine. The investment cost of a static var compensator may amount to SEK 0.48 million/Mvar (€ 0.06 million/Mvar). The plant owner may argue that the value of the extra reactive power from a 100 MVA Powerformer represents a value of at least 15 x 0.16 = SEK 2.4 million (€ 0.3 million) and perhaps about 15 x 0.48 = SEK 7.2 million (€ 0.9 million). In addition, we have to add the economic value of the losses in the shunt capacitor or in the static var compensator.

Let us now assume that the plant owner does not get paid for any extra reactive power supplied to the network. We assume that it is necessary to supply the 37.7 Mvar of reactive power that the conventional generator and step-up transformer can deliver to the transmission network. The plant owner can now reduce the size of Powerformer so that it can generate 100 x 0.85 = 85 MW and deliver 37.7 Mvar to the power system. The rated apparent power of Powerformer now becomes $\sqrt{85^2+37.7^2} = 91.1$ MVA. This means that the plant owner may order a Powerformer with a 9 per cent lower apparent power than the conventional generator and still provide the transmission network with the same amount of reactive power.

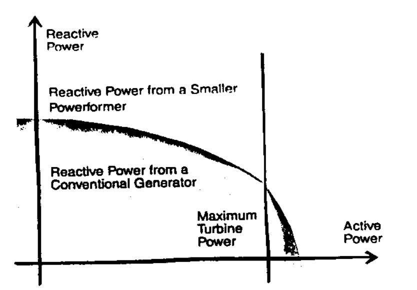


Figure 3. Powerformer of reduced size providing the same amount of reactive power as a conventional generator and step-up transformer.

Figure 3 illustrates the capability of Powerformer of reduced size and unchanged reactive power capability.

ILLUSTRATIONS

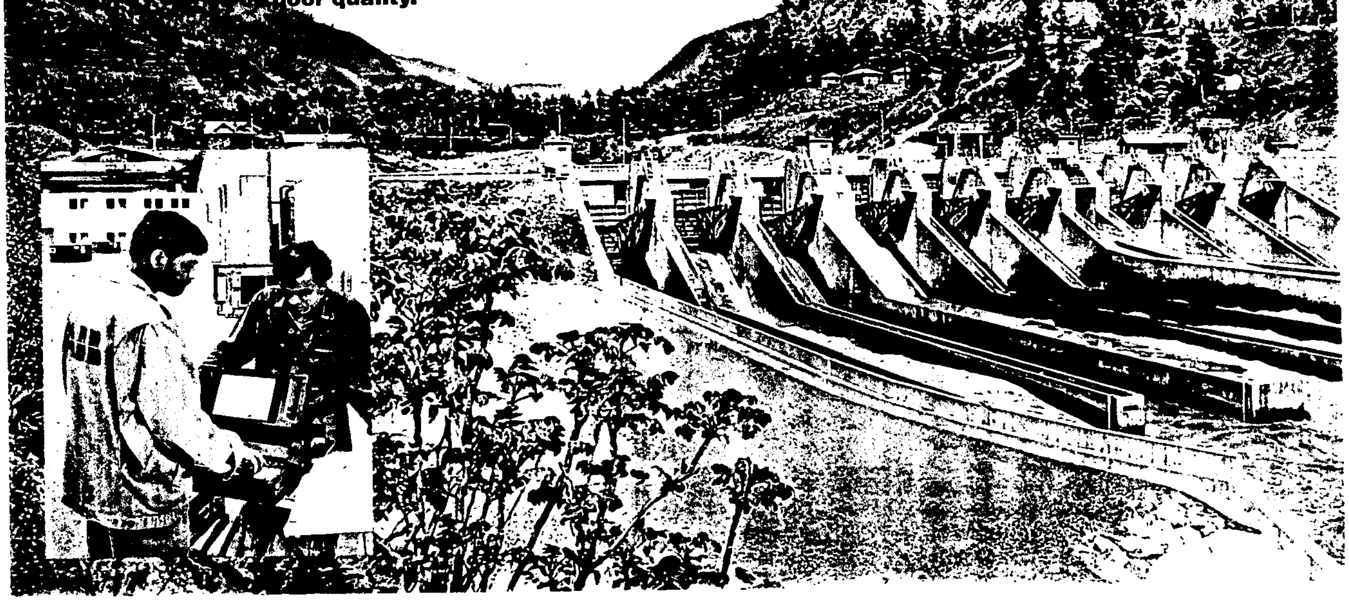
ILLUSTRATIONS (Cont'd)

ILLUSTRATIONS

ILLUSTRATIONS (Cont'd)

How much could

SWECO has compared the conventional energy technology at the Uri Hydropower Plant in India with the high-voltage generator Powerformer. With a Powerformer installation the underground volume will be reduced by one-third. And this can have major benefits during the designing of underground structures, when, for example, the rock is of poor quality.



In the rear-view mirror

How should ALSTOM meet the "threat" from Powerformer?

Alain Lacaze: Powerformer came like a bombshell

When ABB launched the high-voltage generator Powerformer in the spring of 1998 it hit the competitor ALSTOM in Paris like a bombshell. Nobody knew what the new technology would mean for the power generation industry, and a large number of people at ALSTOM started to analyze the situation and investigate alternative action plans. One of them was Alain Lacaze, who was responsible for the co-ordination of R&D activities in the turbogenerator business.

Alain Lacaze was a member of a working group that analyzed how ALSTOM should meet the "threat" from Powerformer with the turbogenerator business as starting point. "We assessed different alternatives," he recalls. "Should we go against ABB, or should we follow them? It was a particularly difficult situation, as we weren't experts in the field of high-voltage cables and were therefore obliged to obtain outside assistance to get answers to many of our questions."

In mid-1999 the 50-50 jointly owned company was formed by ABB and ALSTOM. Effective May 10 this year ALSTOM has full responsibility for the manufacture and marketing of the new high-voltage generator. As a consequence of this, Alain Lacaze now has the opportunity to compare the results of the working group's study with the real Powerformer generator system.

Today, he is primarily studying Powerformer to see how the design and manufacture can be optimized, which will make it possible to offer customers a cost-effective product.

Alain Lacaze.

In the opinion of Alain Lacaze, a standardized design of Powerformer and a few model types are the way ALSTOM must follow. "I think we must first decide which markets we are to focus on and then introduce more or less uniform models of Powerformer in each market," he says. "If we limit the number of models, we can also devote more resources to refining and improving those we already have."

ave been saved if...?

Sten Palmer, project manager at SWECO.

Despite the application of conventional energy technology, the Uri Hydropower Plant in India is comparatively speaking an ecologically sound power plant. But it would have become even more environmentally friendly with the high-voltage generator Powerformer.

This is one of the conclusions in a report prepared by SWECO, Sweden's leading architectural and technical consulting company.

"Besides a substantial improvement of the environmental factors, Powerformer will substantially reduce the costs of the civil works. Other benefits are a higher efficiency as well as lower operating and maintenance costs," says Sten Palmer, project manager at SWECO. "To sum up, all factors exclusive of the higher efficiency show a net present value of some € 8.0 million in favour of the Powerformer installation."

SWECO's engineers and architects have played a major role in the planning and implementation of power plants with a combined capacity of over 33,000 MW; half of this relates to hydropower. The company's activities comprise initial studies, planning, design and management carried out by specialists, who are highly qualified in all aspects of hydropower development.

A cost reduction of 16 percent

Sten Palmer and his colleagues at SWECO have compared a system based on a high-voltage 150 MVA Powerformer with a conventional system comprising a 136 MVA generator and step-up transformer in the Uri Hydropower Plant. Only those components and structures that have been changed in the Powerformer installation have been studied and the corresponding cost change has been estimated.

For the underground civil works a 22 percent reduction of the cost for the machine hall, draft tube gallery and appurtenant tunnel systems has been identified. No substantial cost change has been found for the electromechanical equipment. A cost reduction of 16 percent has been identified for the ventilation system in the underground caverns and tunnels.

Higher efficiency

"An additional power production of 17 GWh/year due to the higher efficiency has been identified," says Sten Palmer. "Compared to an average annual production of 3,200 GWh, the additional power corresponds to 0.56 percent."

Sten Palmer states that it is beyond doubt that it would have been a distinct advantage to have a Powerformer installation in Uri Hydropower Plant. The higher energy production alone speaks in favour of this. The risks of faults are reduced and consequently also the operating costs. From the environmental viewpoint there are substantial benefits, because the step-up transformer is omitted in a Powerformer installation, which eliminates the risks associated with the handling of transformer oil.

"In addition, the size of the underground installations is reduced. The transformer hall is no longer needed, which facilitates the designing of the underground caverns. This means that the underground volume will be reduced by one-third. And this can have major benefits during the designing of underground structures when, for example, the rock is of poor quality.

"Due to the major benefits of Powerformer for underground power plants a Powerformer alternative is today generally included in the initial studies we carry out for our customers," states Sten Palmer. "The high-voltage generator is not so widely accepted that we can include it everywhere, but in those cases where we see that the customer can earn money with Powerformer, we then propose it as an alternative."

What do you think the market for Powerformer will look like in the future?

"As I view the situation, Powerformer in the long term should take nearly the entire market for underground hydropower plants, while above ground there is a fifty-fifty chance."

A suggestion about achieving this?

"The industry is conservative," continues Sten Palmer. "Only a few Powerformer generators have so far been built and are in operation. Customers and investors are consequently a little anxious that the high-voltage generator will not meet all the demands over a long period of service. However, everybody is aware of its potential. In my opinion such a large group as ALSTOM Power could very well participate as investor in projects, provided that Powerformer is included in them. This would substantially speed up the process and result in more Powerformer installations around the world."

Facts

The Uri Hydropower Plant is located on the river Jhelum in the Baramula district of Jammu and Kashmir State in India. The plant is a run-of-river scheme without any storage of water. Its installed power capacity is 480 MW and the average power production 3,200 GWh per year.

Photo: ABB

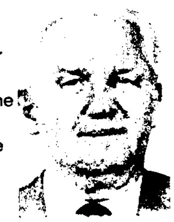
Yves Carette: Strong continuation of a successful launching

On May 18 ABB concluded the sale of its 50-percent share in the jointly owned company ABB ALSTOM Power to its other owner, the French ALSTOM. With the conclusion of the sale, ALSTOM also took over the responsibility for the manufacture, marketing, engineering, product development and service of Powerformer from ABB, which, however, is keeping full ownership of the Powerformer technology. At ALSTOM Power they are now preparing the global marketing of the revolutionary Powerformer technology.

Yves Carette is operating on a corporate level in ALSTOM Power's headquarters, where he is reporting to the Chief Technical Officer. His main task is to deal with technical evaluations.

"Powerformer is an extremely interesting product, in both the hydropower and the thermal power sectors," he explains. "But we have to start somewhere and we then consider that the largest potential today is to be initially found in the hydropower sector. Reasons for this are that we see here a market in many countries and that Powerformer saves a lot of money in terms of the civil works. This naturally has its greatest impact in the industrialized countries, where the civil works represent a large cost for a project." Yves Carette sees a large market potential for Powerformer in a number of countries and continents.

"The entire Nordic region, the whole of North America and several South American countries are interesting, because large hydropower resources are to be found there," he says. "But we mustn't forget the thermal power sector. Even if hydropower is of the greatest interest in the short term, the largest volumes are probably to be found in the thermal power sector, when viewed in a longer term."



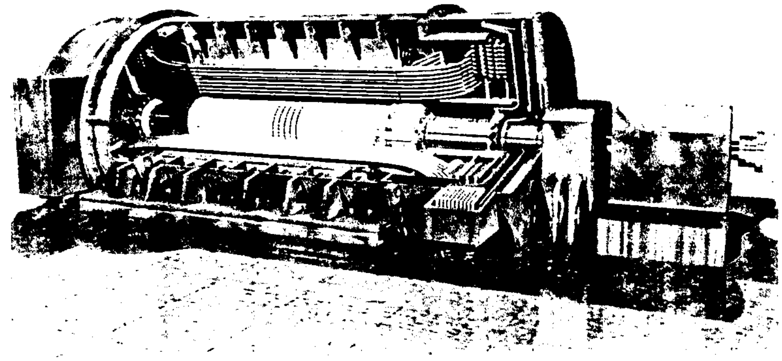
Yves Carette.

ALSTOM Power has today quoted several installations with Powerformer all over the world. "The really good opportunities in the the hydropower sector are first to be found in the small and medium-size output range," he explains. "But we also meet the toughest competition there. It is therefore extremely important that we inform our customers that Powerformer is a technically reliable product that is worth its price. And we'll also be able to do this when we can demonstrate further reference plants." ■

> **"The entire Nordic region, the whole of North America and several South American countries are interesting because large hydropower resources are to be found there"**

The story of Powerformer

The new, revolutionary high-voltage generator Powerformer was launched at the beginning of 1998. Round high-voltage cable is used in this generator instead of the square insulated copper conductors to be found in a conventional machine.



Powerformer for thermal power application.

Powerformer can be connected direct to the high-voltage transmission network. It has a higher efficiency, fewer components in the power plant as well as lower operating and maintenance costs compared with a conventional generator. In addition, Powerformer has a smaller impact on the environment, because a step-up transformer is no longer needed, and its energy losses are lower.

1990
Idea conceived by inventor Mats Leijon.

1991
"Something you have missed?"

1992
"It's impossible!"
"Keep it secret!"

1994
Harry Frank, ABB Corporate Research: "OK, run!"
Presentation to the country management of the Swedish ABB, direct response.

1995
May. First contact with a customer, the Swedish energy utility Vattenfall.
October. Basic layout ready.
November. Decision to build a prototype generator, 11 MVA/45 kV, for installation at Porjus.

1996
April. A group of eight design engineers from ABB ALSTOM Power Generation starts working on the prototype.

1997
March. Cable specified, manufactured, tested and delivered.
July. Winding of the stator starts.

1998
February. Presented to the global media.
April. First operation in the power plant.
June. Inauguration at Porjus.
October. First commercial contract signed for a turbogenerator, 42 MVA/136 kV, for Eskilstuna Energi & Miljö, Sweden.

1999
March. Contract for a hydropower generator, 75 MVA/155 kV, signed with Vattenfall.

2000
May. World's fourth Powerformer for Höljebro Hydropower Plant.
June. Running test of the 42 MVA/136 kV unit for the Eskilstuna CHP plant.

2001
March. Commissioning of yet another high-voltage generator, this time in Porsi Hydropower Plant on the Lule river.
March. Inauguration of the Eskilstuna CHP Plant with Powerformer.

ALSTOM

POWERFORMER

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APPENDIX 3

"Powerformer goes horizontal at Eskilstuna"

"International Turbomachinery"
July/August 2000

Powerformer goes horizontal at Eskilstuna

After two years successful operation of the prototype unit in a hydro plant in northern Sweden, the first example of Alstom Power's high-voltage 2-pole generator to be horizontally configured for installation behind a steam turbine or gas turbine is about to enter service in a new district heating plant at Eskilstuna

Reprinted for ALSTOM Power (Sweden)AB

Powerformer goes horizontal at Eskilstuna

Following two years successful operation of the prototype unit in a hydro plant in northern Sweden, the first example of Alstom Power's high-voltage 2-pole generator to be horizontally configured for installation behind a steam turbine or gas turbine is about to enter service in a new district heating plant at Eskilstuna

For more than 100 years the design of an electric generator has remained basically the same. True, as improved insulation materials became available power ratings increased and improved cooling systems were introduced, but always the generator was a high current, low voltage device. A typical generator output voltage is between 10 and 25 kV.

This all stems from the work of James Clark Maxwell who, in the middle of the 19th century, determined the equations which cover the basic design of the generator. With the insulation materials existing at that time low voltage was a necessity and so higher power was achieved by increasing the current. This has been the guiding principle ever since.

All during this time developments in high-voltage insulation was the preserve of the high-voltage cable manufacturers. They worked outside the power generation business and were never a partner in a turnkey contractor building a power plant. Low-voltage and instrumentation cables were supplied for the auxiliary systems inside the power plant, but the installation of high voltage cable for urban distribution systems and to cross environmentally sensitive areas, and link offshore islands to the mainland were always separate contracts.

About 30 years ago XLPE (cross-linked polyethylene) insulation with its high dielectric strength was developed for high voltage cables. As more experience of this material was gained, so about ten years ago engineers in Sweden started to look at the possibility of building a high voltage generator using a stator winding made with an XLPE insulated cable. If it could be designed for a voltage of say 132 kV there would be no need for a generator transformer and the associated MV switchgear: the generator would be connected through a circuit-breaker straight to the grid.

It would be 1994 before the decision was made to go ahead with development, and in May 1995 a contract was placed by Vattenfall for a first unit to go into a hydro station at Porjus, on the Lule river as it crosses the Arctic Circle in Northern Sweden. This first unit rated 11 MVA, 45 kV, and rotating at 600 rev/min came into operation in June 1998. This is an addition to an old power station which has become the Hydro Power Technology Centre, owned jointly by Vattenfall and Swedish industry, to study new developments in hydro power in a working power system. It has also meant that many countries with interest in developing new hydro plants, or as is the case in Scandinavia, refurbishing old stations have sent people to Porjus to see Powerformer for themselves. The Porjus unit has had a reliability of 100 % during its 2 years of operation. At the time of writing it has accumulated 8500 operating hours.

But the really big market in the future is for Powerformer in turbo application which could be linked to a steam turbine or a gas turbine. Porjus had been in operation only three months when Eskilstuna Energi & Miljo (EEM) the municipal utility in this town, about 160 km west of Stockholm, placed an order for the first turbo Powerformer for a 38MW extension of their district heating plant.

This plant extension comprises a circulating fluidised bed boiler burning biomass, mainly forestry and sawmill wastes and supplying steam to a 2-speed VAX type back-pressure turbine driving the centrally mounted Powerformer. The plant is rated at 38 MW with 85 MJ/s of district heating load. The Powerformer is rated at 42 MVA, 136 kV at 3000 rev/min and power factor 0.933.

Building Powerformer

Although the Powerformer rotor is similar to that of a conventional generator with brushless excitation, the assembly of the stator is significantly different. The stator frame is stood on end and the winding is built up from continuous 300 metre lengths of XLPE insulated cable. The cable is drawn up a slot and at the top of the frame is passed down the diametrically opposite slot. Almost the entire length of 300 m is drawn through the first slot. Thereafter the cable is passed up and down to create the turns. Each layer of coil is packed in the slot with a rubber wedge which holds it in place.

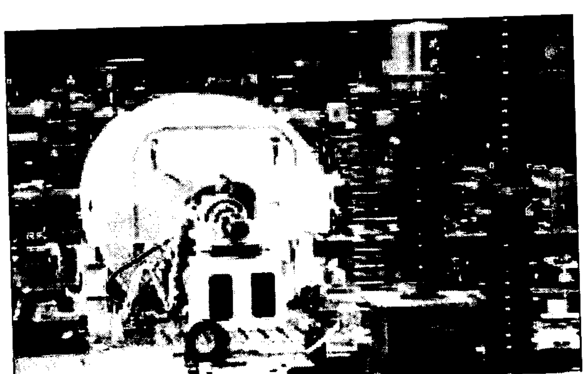

Fig 1. The completed Powerformer for Eskilstuna is shown here being set up in the factory at Västerås at the beginning of June for electrical tests which were witnessed by the customer and Lloyd's Register inspectors

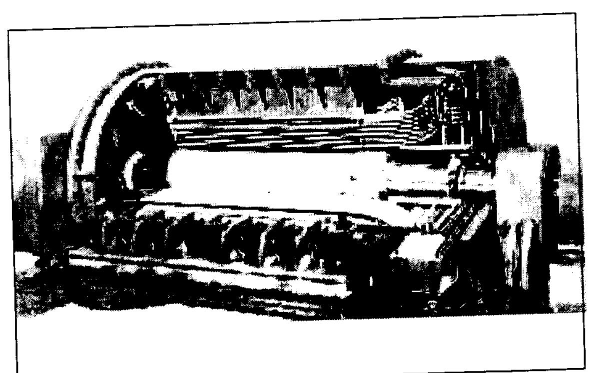

Fig 3. Cut away model of Powerformer showing the basic arrangement of the stator winding. Though not used here, low voltage windings for plant auxiliaries can be fitted around the main winding. Rotor is similar to conventional machine with brushless excitation

The end windings are unlike the conventional generator since the loops of cable between the slots are bound in threes with tape to form a knitted ring of cable around the rotor. There are two points to be noted, since an insulated cable with ground potential at the outer diameter is used for the windings there is no potential difference between the winding surface and the stator body or between adjacent coils. Also since a cable section is circular there is a uniform field strength around it, unlike in a conventional winding with its square copper sections which produce a higher field strength at the corners. Since the winding is at a higher voltage the current is substantially lower. In the machine for Eskilstuna the stator current is about 170 A whereas in a conventional low voltage generator of the same rating, the current would be nearly 2000 A.

Powerformer therefore runs cooler and has fewer copper losses but the larger stator core mass due to the larger number of winding turns results in higher iron losses. However, on balance the Powerformer comes out at a higher efficiency between 0.5 and 2 percentage point better than a conventional generator and step-up transformer arrangement. For a gas turbine or steam power plant of 100 MW size the output increases by approximately 1 MW. For Eskilstuna Powerformer the efficiency is 98.23%.

The rotor is air cooled but there is a water cooling circuit for the stator with a ring of cooling pipes passing through the core. Ordinary tap water can be used: deionised water is not called for as the electric field is confined within the cable winding.

The machine for Eskilstuna was completed earlier this year and was submitted to factory tests in mid June witnessed by representatives of EEM and Lloyd's Register. It was first show to operate at its rated voltage of 136 kV and at 177 kV during an overexcitation test: a world record generator terminal voltage.

On 14 June, the Powerformer stood the sudden short circuit test from 100% of rated voltage. As expected, the currents at the test were close to 1000% of normal load current. This is the highest possible current which may flow from Powerformer in case of faults in the adjacent transmission network.

The following day, a second test involving a sudden single phase-to-earth fault showed that the voltage on the two healthy phases temporarily exceeded 175% of normal operating voltage. This is the highest possible voltage which may stress the insulation of the stator winding in case of faults in the cable connecting Power-former to the transmission network.

On successful completion of the tests the machine was shipped from the factory in Västerås at the end of June and is planned to start operation in October. The plant is due to be handed over to EEM in March 2001.

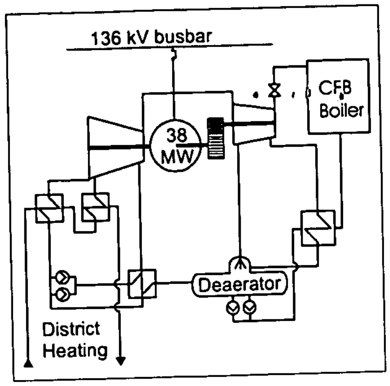

Fig 2. Eskilstuna district heating extension is directly linked to the 136 kV grid, but uses existing 10 kV auxiliary circuits.

Future options

With a first horizontal unit now starting in operation what are the possibilities for future applications. It is notable that three of the first four installations are all for extensions of hydro plants. This is likely to be an ongoing market because of the plans to extend and reequip some of the older hydro stations. In March 1999 Vattenfall ordered their second Powerformer, which is rated 75 MVA, 155 kV for a refurbishment of the Porsi station on the Lule River above Porjus. The new generator will replace one of the three units in the power station and will be coupled straight into the 130 kV grid serving the communities along the river. Then in June this year, Fortum Kraft AB, ordered a Powerformer rated 25 MVA, 80 KV for the Höljebro power station.

As yet no gas turbine application has appeared. The frame size of the Eskilstuna machine has a full capacity of 90 MVA, using a slightly different cable in the winding. At this rating it would fit into a single shaft combined cycle block with for example Alstom Power's GT8C2 gas turbine.

For a combined cycle application the currently quoted Powerformer ratings are for power up to 200 MW and voltage up to 170 kV. What would be the benefits for a combined cycle of installing Powerformer?

First there would be no generator transformer and no auxiliary transformers and the associated MV switchgear. Alstom Power have made a concerted effort to simplify the auxialliary systems and fit them in factory assembled packages which can be fully tested before shipping to site. Part of this development has been to standardise on 415 V supply for most auxiliary components. The exceptions are the boiler feed pumps and the static starting device which typically take supply at up to 3 kV.

Given that the length of the winding determines the Powerformer output voltage, and that the cable is fully insulated, it is possible to lay a second shorter winding around the main winding to generate the auxiliary voltages at 415V For the static starting device a transformer would be required to step down from the grid but this would be a relatively small device and could possibly be incorporated in a bay of the cabinet housing the system. In fact a second winding, for example at 3 kV could also be fitted to power the larger auxiliaries such as boiler feed pumps.

In evaluating Powerformer for their project, EEM estimated that they would save 15% on initial cost by not having a generator transformer nor MV switchgear, nor auxiliary transformers and as a result having a smaller footprint. Elimination of a device carrying a large oil volume and all the precautions to protect against fire or leakage is another benefit. There are no auxiliary windings on the Powerformer since EEM will tap into existing auxiliary voltage supplies on the site.

The same benefits would accrue with the combined cycle, although being a new plant on a green field site the savings on land and auxiliary equipment might be greater. For a large aero derivative machine designed to run in simple cycle mode for mid-load duty in a distributed network there would be just two packages: the gas turbine and the Powerformer.

Finally we must remember that the improvements of efficiency in power generation have up to now been largely attributable to the improvements in the gas turbine. Now with Powerformer we see the possibility of a significant efficiency gain beyond the turbine flange together with a simplified plant layout and a lighter maintenance burden.

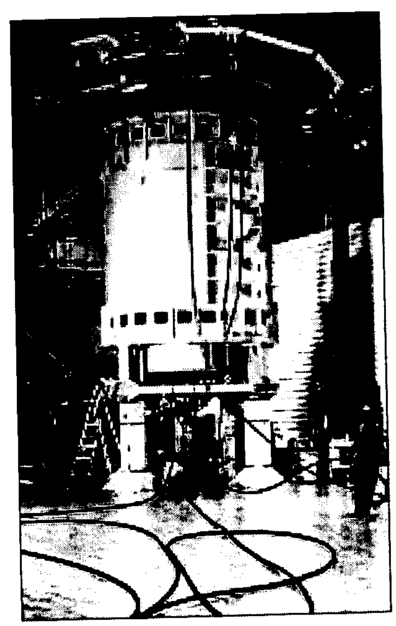

Fig 4. The Powerformer stator winding is made up from 300 metre lengths of XLPE cable threaded through the core slots as shown here.

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APPENDIX 4

Press Release, June 22, 2000:

"ALSTOM Power receives major order to supply fourth Powerformer™ for the Höljebro Power Plant in Sweden"

ALSTOM **PRESS RELEASE**

ALSTOM Power receives major order to supply fourth Powerformer™ for the Höljebro Power Plant in Sweden

Västerås, Sweden, 2000-06-22

ALSTOM Power has received a new order to supply a high-voltage Powerformer generator to Swedish utility Fortum Kraft AB (earlier Stora Enso Energy AB) which produces electricity in around 40 hydropower plants in central Sweden. This is the world's fourth Powerformer.

The Powerformer, with its unique capability to generate at high voltage, feeding electricity directly into the transmission network without the need for a step-up transformer, will be installed at the Höljebro Hydropower Plant, on the Ljusnan river, just south of the town of Söderhamn. The Powerformer will replace the two oldest units in the power plant dating from the 1930s and will be connected directly to the 80 kV network. The new generator will be installed in an extension to the existing powerhouse. The upgraded power plant is scheduled to enter into operation in June 2001.

"Powerformer represents a significant step forwards in technology development. After a century with conventional technology, we have been eagerly awaiting a high-voltage generator like this. And what makes the situation still better is that the environmental benefits are so tangible, such as the absence of a step-up transformer," comments Sven Andersson, Production Manager at Fortum Kraft AB.

"It is very gratifying for us that Fortum Kraft AB has chosen tomorrow's technology for the production of electricity," says Magnus Jonasson, of ALSTOM Power, Västerås, and he continues: "The Höljebro installation will give us good opportunities to increase our market shares, both nationally and internationally. Powerformer generators having the same output as the Höljebro machine can really become 'best sellers' in the future, not least against the background that many conventional generators in, for example, Sweden must be refurbished in the future.

Comparative Life Cycle Assessments of Powerformer and traditional generator technology show that reducing the size of the power plant and the number of components lowers the associated maintenance costs and the energy losses. Installing Powerformer in Höljebro together with the environmental benefits of the high-voltage cable technology applied in the generator will give a result equivalent to a value of approximately SEK 15 million (approximately US$ 1.7 million).

The Swedish National Energy Administration is also backing up the installation of Powerformer in Höljebro by providing Stora Enso Energy AB with support for the project.

With revenues of approximately 10 billion euros, ALSTOM Power is a leading supplier of power generation services and equipment and employs over 50,000 employees worldwide. It is wholly owned by ALSTOM, the world leading infrastructure provider for the energy and transport markets.

APPENDIX 5

Press Release, June 22, 2000:

“Powerformer™ sets new world record”

ALSTOM **PRESS RELEASE**

Powerformer™ sets new world record

Västerås, Sweden, 2000-06-22

ALSTOM Power's revolutionary high-voltage generator, Powerformer, has passed another milestone. Powerformer for Eskilstuna Combined Heat and Power Plant in Sweden has successfully operated at 136 kV during running tests and at 177 kV during overexcitation test. This is a world record in generator terminal voltage.

Representatives of the customer, Eskilstuna Energi & Miljö, together with Lloyd's Register surveryors, witnessed the spectacular test results. The unit for Eskilstuna, the first for a thermal power plant, has a rated output of 42 MVA, a speed of 3,000 rpm and voltage of 136 kV. Conventional generators have rated voltages of the order of 10 kV.

On 14 June, the Powerformer stood the sudden short circuit test from 100% of rated voltage. As expected, the currents at the test were close to 1000% of normal load current. This is the highest possible current which may flow from Powerformer in case of faults in the adjacent transmission network.

The unit also peformed well when subjected to a sudden single phase-to-earth fault on 15 June. In this case, the voltage on the two healthy phases temporarily exceeded 175% of normal operating voltage. This is the highest possible voltage which may stress the insulation of the stator winding in case of faults in the cable connecting the Powerformer to the transmission network.

The Powerformer generator will be connected directly to an existing 136 kV substation, and is compact since it needs fewer components (no step-up transformer, medium voltage switchgear). It also results in greater availabilty and increased efficiency.

The CHP plant in Eskilstuna is scheduled to be inaugurated in March 2001.

Technical Data - Eskilstuna

Output :	42 MVA
Voltage :	136 kV
Frequency :	50 Hz
Speed :	3,000 r/min
Connection :	Direct connection to 136 kV network

APPENDIX 6

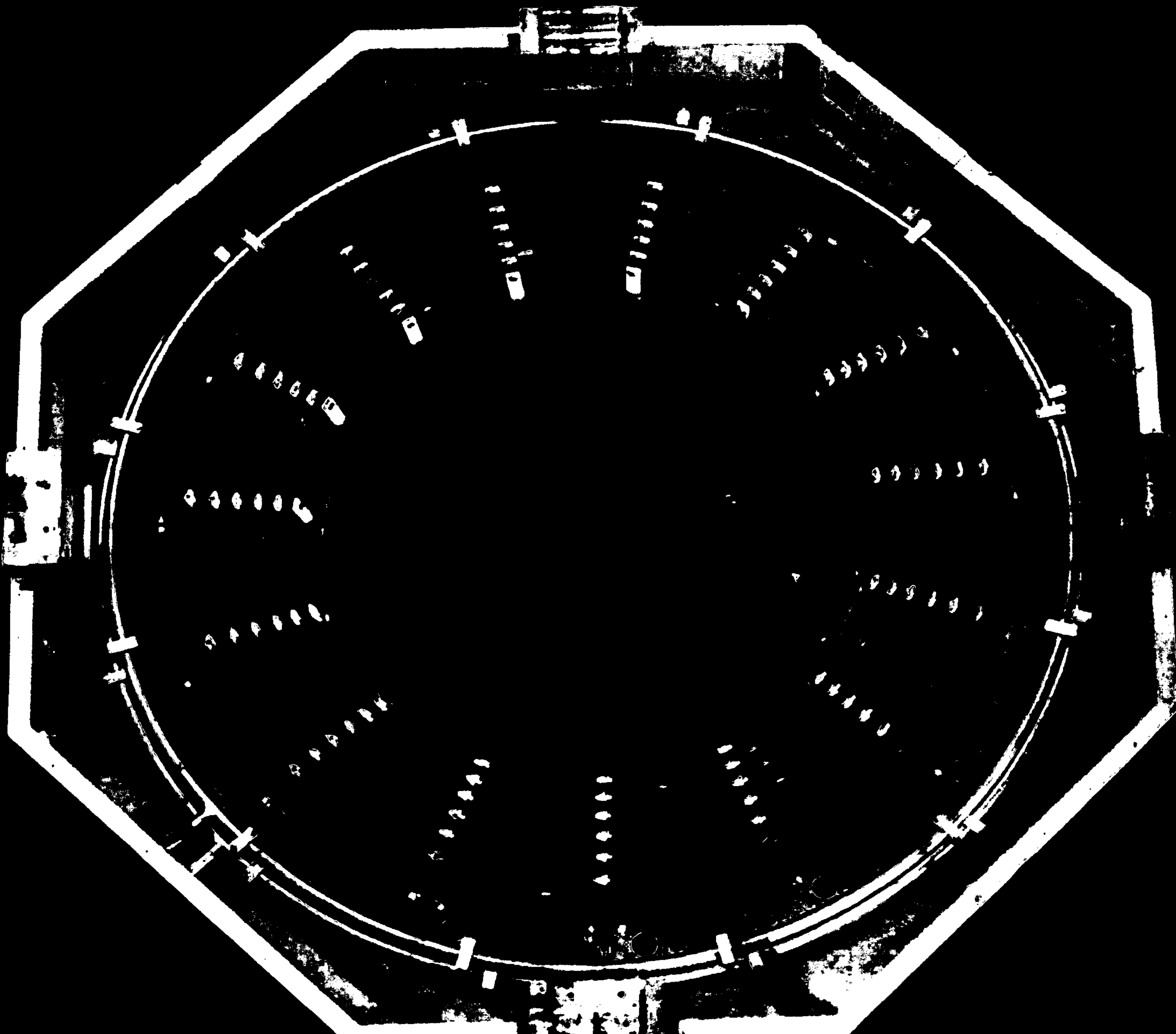
Cover:

“Electra”
April 2000

electra

AVRIL/*APRIL* 2000

N° 189



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IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF:		:
MATS LEIJON ET AL		: GROUP ART UNIT: 2834
SERIAL NO.: 09/147,325		:
FILED:	FEBRUARY 17, 1999	: EXAMINER: ENAD, E.
FOR:	ROTATING ELECTRICAL MACHINE COMPRISING HIGH-VOLTAGE STATOR WINDING AND ELONGATED SUPPORT DEVICES SUPPORTING THE WINDING AND METHOD FOR MANUFACTURING SUCH MACHINE	:

DECLARATION UNDER 37 C.F.R. §1.132

ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, D.C. 20231

SIR:

I, Robert E. Fenton, hereby declare:

1. I am the President of Generation Technology Consultants, Inc., where my mailing address is 2135 Cook Road, Charlton, New York, 12019.

2. My academic background is as follows:

   Bachelor of Science degree in Electrical Engineering from Manhattan College; and

   Master of Science degree in Power Systems Engineering from Rensselaer Polytechnic Institute.

3. My industry experience is as follows:

I have over 30 years of experience in the area of power generation, with the most notable positions as follows:

- **<u>Generation Technology Consultants, Charlton, NY (1997 – Present)</u>**

<u>President/Consultant</u> – Provide expert consultation and technology support relating to generators and power plants worldwide.

- **<u>General Electric Co., Schenectady, NY (1986-1997)</u>**

<u>Power Systems Business – General Manager, Generator Design and Development</u> - Managed and led the design organization responsible for the development of new technology, introduction of new designs, creation of service and upgrade programs for an operating fleet of over 7000 generators rated from 15 MW to 1500 MW. Served as the technology interface with GE generator customers. GE is now, and was then, the leader in both number of generators and technology in the industry.

- **<u>General Electric Co., Schenectady, NY (1980-1986)</u>**

<u>Power Systems Business – Manager, Project Engineering</u> - Managed and led the team responsible for application of generators to new power plants and the technical support for the existing fleet in operation.

- **<u>General Electric Co., Schenectady, NY (1973-1982)</u>**

<u>Power Systems Business – Manager, Application Engineering</u> - Led a team of 12-15 engineers. I was responsible for the decisions on the application of design technology and the introduction of new technology to meet customers' needs and specifications. I also provided frequent customer interface, especially on the most difficult projects.

- **<u>General Electric Co., Schenectady, NY (1967-1973)</u>**

<u>Power Systems Business – Application Engineer</u> – I was a member of the team described above.

4. I have provided a more detailed description of my professional background as Appendix A, attached hereto.

5. In preparing this declaration, I have read and considered at least the following documents pertaining to the above-identified patent application: (1) the patent application (U.S. Serial No. 09/147,325); (2) the Preliminary Amendment filed November 27, 1998; (3) the Office Action dated September 29, 2000; (4) the Amendment filed on March 29, 2001; and (5) the Filing of Declarations Under 37 C.F.R. §1.132, and Further Evidence In Support of Patentability. I have also read the following United States patents: (1) Shildneck (U.S. Patent No. 3,014,139); (2) Elton et al. (U.S. Patent No. 4,853,565, hereinafter Elton); (3) Wood (British Patent No. 1,135,242); (4) Mazzorana (French Patent Nos. 2,594,271 and 2,556,146) (these are French language patents, and I have reviewed the figures, but have not read these French language documents); (5) Grant (U.S. Patent No. 5,325,008); (6) Siemens (British Patent No. 468,827); and (7) Madsen (U.S. Patent No. 3,932,779), all of which have been asserted as prior art against the present patent application.

6. Rotating electric machines such as generators play a key role in the electric power production industry in that they are a basic element of a power station system as a whole. From a cost perspective, a generator is a comparatively small component of a power station, but when a generator becomes inoperable, the entire output of the power station is adversely impacted. Accordingly, as a critical system component, the generator plays an important role in the acceptance of new designs of power generation technologies. While improvements in generator design can have great benefits, the risks associated with adopting unproven designs are carefully scrutinized by risk-averse utility owners. The tendency, therefore, is for utility owners to avoid new risky designs and opt for more conventional approaches that have worked reliably and safely in the past.

7. It is important to distinguish what I will call "ordinary" high-voltage machines from the higher-voltage machines of the present invention, which can be directly connected to a power grid. An "ordinary" high-voltage machine is a machine that typically operates below 15kV and in some cases may operate at 30kV or below. ABB's rotating machines based on the ENKEL technology can operate at much

higher voltages, for example up to 800kV. This distinction is significant, since ABB's machines do not need a transformer to connect to the power grid, which often operates at 200kV or higher. "Ordinary" high-voltage machines on the other hand, generally require a transformer to step up the voltage between the machine (in this case a generator) and the power grid. While ABB's machines may be used at "ordinary" high-voltages, they are unique in that they may also be designed to operate at sufficiently high-voltages to connect directly to the power grid.

8. Of course from a system perspective, eliminating the transformer improves system flexibility, increases efficiency by reducing loses, improves reliability by lowering the number of components, and reduces cost.

9. The notion of eliminating the transformer is not new. For example, my former employer, General Electric Company, studied this in the early 1980s, and more recently in April 2000, by GE Canada.[1] In both cases, then and now, GE concluded that there is no reason to believe that rotating machines can be expected to directly connect to the power grid any time soon, due to the complexity of design parameters that are perceived as limiting reliable operation at high-voltage.

10. In the early 1980s, the Electric Power Research Institute (EPRI, an industry funded research organization)[2] commissioned a study to identify a rotating machine with a high-voltage stator winding that could be connected directly to the power grid without a step-up transformer. However, based on the report from General Electric (EPRI's contractor) published in 1982, EPRI concluded that this was not practical. Since that time, the power industry has virtually given up on attempting to build rotating machines that are able to operate at higher voltages. This is due to the perception that the machine would be based on a complex design that would, in all likelihood, suffer from reliability problems. One perceived problem was heat build-up in the rotor, which would result from the necessarily strong electromagnetic field that tended to focus efforts on a monolith cylinder stator and superconducting materials in the rotor that would be able to avoid heat build-up by lowering conductor resistance.

[1] M. Clark, et al., Changing Insulation Systems – Benefits and Problems, Proceedings of 2000 IEEE International Symposium on Electrical Insulation (2000). See Appendix C.
[2] High-Voltage Stator Winding Development, Final Report, Electric Power Research Institute, April 1984. See Appendix B.

11. GE Canada's more recent (i.e., April 2000) analysis has led them to the same conclusion that "it is not expected to see specification of power system voltages to perhaps 35kV for machines in order to eliminate transformers and breakers." A related observation was that "[t]he advantages of the higher voltage machines are not going to come without careful analysis of all the factors, some of which many of the current generation of machine designers and insulation specialists are totally unaware." Ironically, ABB has shown that the solution was not to employ a more complex solution, but rather, a simplifying solution.

12. Prior to ABB developing the present inventive technology (sometimes referred to as ENKEL technology), there were only "ordinary" high-voltage generators available on the market, requiring a step-up transformer to connect to the power grid. Until ABB released the ENKEL rotating machines, there were no rotating machines on the market that could be directly connected to a high-voltage power grid supplying power 100s of kV. Furthermore, there remains a general belief among industry members that "it is impractical to try to generate at substantially higher voltages with a conventional generator."[3]

13. Regarding the engineers who work in the appropriate field, in my view a person of ordinary skill in the ordinary high-voltage rotating machines art would typically have an undergraduate degree in Electrical Engineering, Mechanical Engineering or a closely-related specialty, and/or five or so years of professional experience.

14. Ordinary high-voltage rotating machines are a specialized technology, in part because so few companies produce such machines. Furthermore, people with purely academic experience in ordinary high-voltage machinery are frequently not informed about the practical, "real-world" design considerations associated with such ordinary high-voltage machines. Practical experience is a crucial requirement for ordinary high-voltage machine engineers. A fault in an ordinary high-voltage rotating electric machine can lead to a failure of the entire machine due to the large electrical and mechanical forces that are at play. Such a breakdown could not only lead to stopped production at a power station, but also

[3] Rabinowitz, R., "Power Systems of the Future (Part 4)," IEEE Power Engineering Review, Vol. 20, No. 8, Aug. 2000, p. 4, col. 2. See Appendix E.

create a hazardous situation for the production personnel working at the power station.

15. Consequently, young engineers work under the close supervision of experienced ordinary high-voltage machine engineers and new designs are carefully scrutinized to prevent using features that are known to be dangerous or pointless. The risk of including an unproven design feature is simply too great. It is this apprentice-type training approach that is generally followed within our industry.

16. Much of the information gathered by "one of ordinary skill" in the ordinary high-voltage rotating machine art is inherited from more experienced engineers. Thus, significant design changes for ordinary high-voltage rotating machines do not occur frequently, but rather, designs evolve incrementally. The authors from GE Canada of the paper included in Appendix C expressed this concern well when they predicted[4] that moving to higher voltage machines is "not a simple matter" because of the large number of factors affected by high-voltage operation including "clearances, bracing, cooling method, corona suppression, winding terminations and cabling, enclosures, cooling medium, slot grounding, grading, contamination, strand, turn, ground wall insulation, etc." If restricted to conventional design practice, I would agree with the authors from GE Canada. However, what I find most interesting is that the ABB ENKEL technology does address all of these factors with a simple design.

17. The invention described in the subject patent application is directed to high-voltage rotating machines and methods for drawing a high-voltage winding through slots in a stator of high-voltage rotating machines. Such machines may be used as generators in power stations, for example, and could be configured to be directly connected to a power grid without an intermediate step-up transformer.

18. From a number of perspectives, the ABB inventors have done something quite remarkable. First, they were somehow able to convince their company to invest millions of dollars in the idea of developing a high-voltage rotating machine – an idea that that rest of industry, including myself, had given up on. Second, they

[4] It is clear that they were unaware of ABB's recent successes.

were able to overcome the challenges of designing and manufacturing a machine that is capable of operating at voltages that exceed 30kV.

19. Traditionally, attempts to design a larger high-voltage rotating machine have focused on increasing the current-carrying capacity in the stator windings, thereby making a compact machine with high power output. However, as the current in the windings is increased, the requirements for the insulating materials of the windings are also increased. As higher currents were achieved, higher temperatures were encountered. Extreme temperatures within the confined area of the machine causes the insulation of the windings to break down, which eventually leads to a failure of the whole machine. Accordingly, the development of insulation systems with good heat resistance became a focus for modern research. The proceedings of INSUCON/ISOTEC '98, the table of contents of which are included as Appendix D, and which pre-date the publication of the ENKEL invention are indicative of these efforts.[5] In retrospect, after seeing ABB's high-voltage approach, it seems that the machine designers had focused the insulation industry on the symptom of the high heat resulting from high current operation, while ABB avoided the problem altogether by employing a high-voltage, and thus low-current, design. Since higher voltage does not give rise to heat problems, it is not necessary to use electrical insulation on the cable windings that can withstand ultra-high temperatures. Thus, to some extent, ABB's contrarian design approach showed that the industry's focus on a high-temperature insulation solution did not point to ABB's more simple solution.

20. By focusing on increasing the current capacity of the windings in designing an ordinary high-voltage machine, certain practical limits are encountered, such as failures resulting from high-temperature operation. According to conventional design practice, it was necessary to provide either cooling for the windings, or provide an insulation system that can withstand the heat. Both of these options are unattractive. Cooling the windings with a fluid is unattractive since it adds to the system complexity, and therefore the manufacturing cost of the machine. Also, some coolants are flammable, which can present a fire hazard. Increasing the insulation of the windings is also problematic. As the insulation becomes

thicker, it will become difficult to position a large number of winding turns without the machine getting prohibitively large. Furthermore, heat transfer across the insulation from the winding to the outside environment becomes severely restricted.

21. Designing an ordinary high-voltage rotating machine to operate at power grid voltages is not a simple matter of scaling-up a lower voltage machine. This point was highlighted in the GE Canada paper:

> Although some work has been done to produce air cooled machines at voltage ratings above 15 kV, it is not a simple matter. . . . Things that were minor problems at lower voltages will become major problems on the new machines. Designers and users will require a new mind set to be able to build and maintain reliable higher voltage machines. The advantages of the higher voltage machines are not going to come without careful analysis of all the factors, some of which many of the current generation of machine designers and insulation specialists are totally unaware.[6]

These are the challenges that ABB faced, but they solved them with a surprisingly simple design.

22. In the 1990s the use of filled materials in insulation systems became of interest as an alternative to asphalt mica and synthetic resin mica. However, it was believed that ". . .this concept has set in motion a new wave in insulation development, with variations over the next decade that may radically change the generator or motor, as we know it today."[7] In light of this prediction of radical changes to generators and motors, it is even more impressive that the engineers at ABB have designed a solution that is not more complex. Thus, while others focused on more complex insulation schemes, ABB used a "systems" approach and, as a result, was able to use a more simple insulation system than others would have expected.

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[5] see, e.g., M. Tari et al., Advanced Technology of Stator Coil Insulation System For Turbo-Generator, Proceedings of INSUCON/ISOTEC '98, at 78 (1998). See Appendix D.
[6] M. Clark, et al., Changing Insulation Systems – Benefits and Problems, Proceedings of 2000 IEEE International Symposium on Electrical Insulation (2000).
[7] see M. Clark, et al., Changing Insulation Systems – Benefits and Problems, Proceedings of 2000 IEEE International Symposium on Electrical Insulation (2000).

23. The high-voltage electric machine described in this patent application is a "game changer." As reflected in the EPRI study, virtually the entire industry between the mid-1970's and the mid-1990's thought (and some still hold this view) that superconducting generators were the only way to achieve the goal of designing a rotating machine for generating very high-voltages. The general thought was that in order develop an increase in flux, either an increase in the amount of amperage, or the number of turns in the rotor would be required. Because the space in the rotor was limited, efforts were focused on increasing the current through the rotor winding. However, increased current results in increased resistive losses. Accordingly, superconducting materials were viewed as the solution to combat the resistive losses. As far as I know, there is only one superconducting ordinary high-voltage rotating machine in use today, and no superconducting higher voltage rotating machines in use. However, it is used as a testbed environment as part of a $200M program funded by the Japanese government.

24. In arriving at their invention, the revolutionary development by ABB was not in a new material, or a new composition, but rather, taking a different look at the problem. ABB recognized that, contrary to an at least 70 year-old industry tradition, one could design a high-voltage rotating machine by focusing on voltage, rather than current. As a consequence, many of the problems that had been confounding the industry regarding the insulation system could be overcome. With lower currents, which is possible by operating at higher-voltage, the insulation system no longer needed to be designed for such extreme temperatures, nor was liquid cooling always necessary. Furthermore, a flexible cable having an insulation system can be used for a full turn of the winding enabling the use of a semiconductive outer layer which will confine the electric field therein. The winding includes an inner semiconducting layer in electrical contact with a conductor, a solid insulation layer surrounding the inner semiconducting layer, and an outer semiconducting layer surrounding the solid insulation layer. ABB's insulation system was not recognized or considered by the industry since, as discussed above, the industry was pursuing a high-current approach to solving the problem of developing larger ordinary high-voltage rotating electric machines. By focusing on a high-current approach to achieving a high-voltage rotating electric machine, the insulation system of the ABB invention would have never

been considered for at least the following reason: the solid nature of the insulation materials would not be able to withstand the extreme temperatures that would be experienced at the current levels being sought, and breakdown would be certain.

25. A long time ago, people had thought of the idea of using flexible conductors in electric machines, however, our experience was that they were seeking a way to lower the cost and improve the reliability of these devices. The Shildneck patent is an example of such a machine. The idea of using flexible conductors or cables to significantly increase the voltage rating of the generator was not even imagined. This is likely because of the significant and almost overwhelming technical challenges in introducing very high-voltages into electrical machinery. When cost savings did not result from the trial of using flexible conductors, the programs quickly died.

26. It has been conventional practice to use a rigid metallic bar winding that has strong physical properties that can withstand the vibrations and stress of operating in a high-power environment. Using a flexible cable for the windings is completely contrary to conventional practice because the high currents in the windings tends to create large vibrations and stress on the end windings. Based upon my understanding of how the ABB invention works, it is clear that the inventors realized that these problems would simply go away if the current in the windings was decreased by operating at a higher-voltage.

27. Figure 1 illustrates an end-winding portion of a conventional machine that has the conventional rigid bar-type windings. As shown in Figure 1, the rigid bar windings must be pre-formed in separate segments and then separately installed and connected to each other by joints in the end-winding region, Region B. With the use of rigid bar-type windings, it would not be practical to have a continuous winding for all of the turns in the stator. As can be appreciated by one of ordinary skill in the rotating machine art, the manufacturing process of winding a stator is a difficult one involving considerable skilled labor. Shown in Figure 2 is a cross section of a typical bar-type winding, which is made of many segments of rigid metal bars that together form the larger winding.

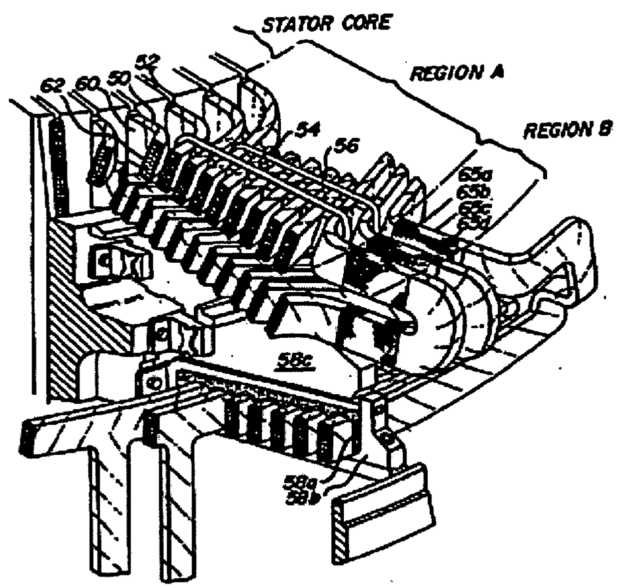


Figure 1 – Machine Having Conventional Bar-Type Machine Windings

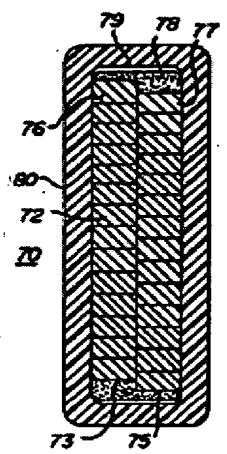


Figure 2 - Cross Section of Conventional Bar-Type Winding

28. Figure 3 illustrates a machine that has ABB's flexible cables for stator windings. As shown in Figure 3, the flexible cable 6 is continuously run through the stator slots 7. Accordingly, there is no need to connect the windings to one another in the end regions. Figure 4 shows a more detailed view of the end-winding region of a machine using ABB's flexible cable windings. By comparing these two figures with Figures 1 and 2 above, it can be easily appreciated that there are many advantages to winding a machine with ABB's flexible cable. The machine includes turns of the winding that are continuous, thereby enabling the avoidance of the problems associated with not containing the electric fields within the windings in the end-winding region experienced using the conventional bar-type windings. While some cable joints may be formed in the end-winding region, certainly every turn in the winding does not include a joint. Also, the ease with which a machine using ABB's flexible cable windings may be wound is a significant advantage from a manufacturing perspective. There will be no need to pre-form the windings. Also, there is no need to form connections and joints for every turn.

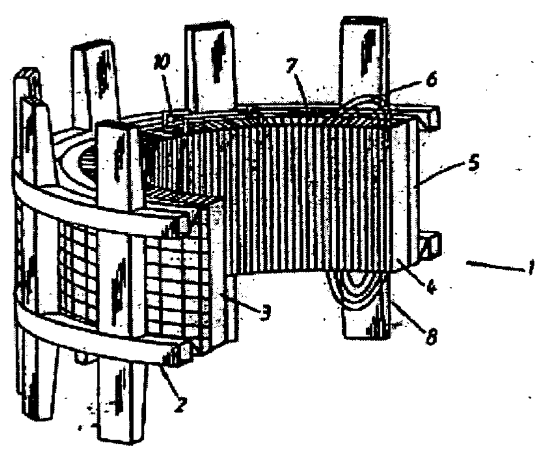


Figure 3 - Machine Having ABB's Flexible Cable Windings

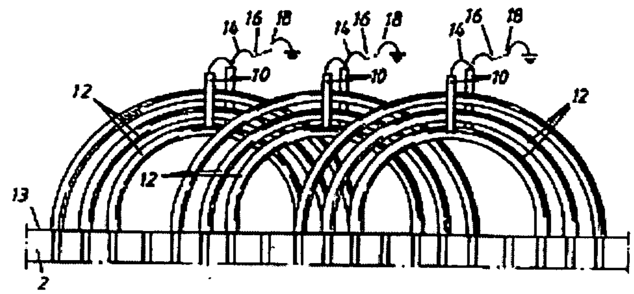


Figure 4 - Detail of End-Winding Region of Machine Having ABB's Flexible Cable Windings

29. As a general matter, rotating machine engineers would not have been motivated to use a flexible cable for the windings in modern machines because the industry had perfected the conventional "bar winding" approach to designing machines, and thus there appeared to be no commercial advantage to substituting a cable winding such as ABB's for the "bar windings" in machines running at ordinary high-voltages. In fact, the experience at GE based on the Shildneck invention (see U.S. Patent No. 3,014,139) demonstrated that this was not economical. However, ABB determined that by using a flexible cable with the particular insulation system as a winding in a rotating electric machine, not only would the machines be able to operate at power-grid-level voltages eliminating the need for step-up transformers, but the machine design would be very simple, perhaps facilitating the acceptance of the design by the risk-averse utility industry. There would be a huge advantage in having a machine that (a) operates at high-voltage so that step-up transformers are not needed, (b) is able to be manufactured without extravagant cooling techniques, and (c) is based on a relatively simple design so that manufacturing and maintenance problems are reduced.

30. Rotating electric machines using ABB's ENKEL technology are fundamentally different than conventional machines. Figure 5, below is a top view photo showing a stator with cable windings according to the present invention.

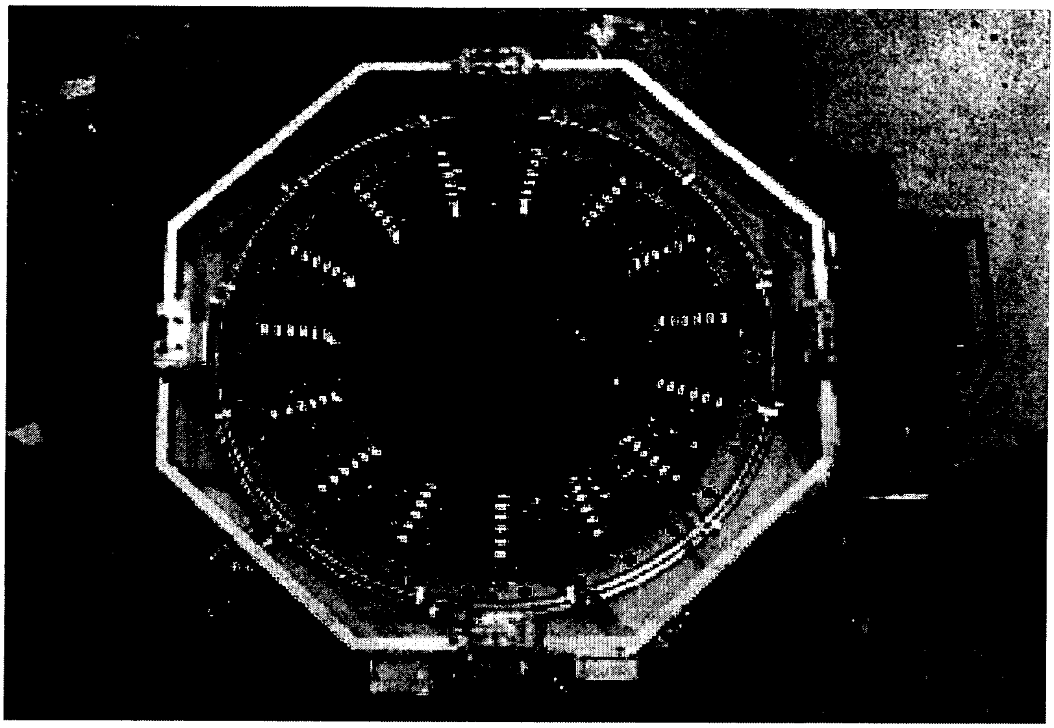


Figure 5: Top View Stator with Cable Windings of the Present Invention

31. The cables in the stator of Figure 5 are continuously looped through the stator slots. In conventional machines, the windings are made of rigid "bar windings" that are fit into the stator slots. Winding a stator with conventional "bar windings" is a labor-intensive job since each of the individual bars must be pre-formed, then "wound" into the stator. Since the winding cable used in the machines of the invention is flexible, the winding process does not include pre-forming the windings, but rather, threading the continuous cable making up the winding turns through the stator slots. One of the reasons that conventional "bar windings" were developed to be mechanically rigid, is to cope with the vibrations due to the electrical forces, which are proportional to the square of the current. Rigid bars provided a natural solution to the attractive and repulsive forces placed on the end-winding portions of the bars due to the currents in the windings interacting with the external electric fields created by the graded voltage from

where the winding emerges from the stator up to the line voltage. The cable used in the windings of the ABB invention can have its outer surface grounded, thereby containing the e-field within the cable. Furthermore, the vibrations are significantly lower due to the high-voltage operation (and thus, lower currents). Consequently, the mechanical integrity of the cable windings in the ABB electric machines is easily assured.

32. Functionally, the more simple[8] generator of Figure 5 can operate at 30kV and above, while conventional generators can not, at least not for any sustainable period of time. As I understand it, the high-power cable used as windings in the generator of Figure 1 is made up of a coaxially-arranged inner conductor surrounded by first, a layer of a semiconducting material, which is itself surrounded by a layer of a solid insulation material, which in turn is surrounded by an outer layer of a grounded semiconducting material. This particular insulation system for the cable winding enables the winding to hold the high-voltage without risk of partial discharge. It is understood that "bar"-type windings are not capable of operating at such high-voltage levels, at least not with modern insulation systems. These further requirements are the main reason that virtually no one is trying to operate at such high-voltage levels.

33. Constructing rotating machines for high-voltage applications gives rise to a number of problems that are not present in conventional rotating machines. For example, to gain a higher voltage, more windings are needed than in conventional machines. Having more winding turns positioned next to each other gives rise to unique cooling problems, and winding vibration problems that can cause the windings to become damaged. Logically, then, one would think that adding more turns to a machine would result in more problems (thermal, discharge, reliability, etc.) being encountered. However, ABB have proved just the opposite: from a system-level perspective, the high-voltage ENKEL machines reduce the number of problems.

34. Attempts have been made, employing various complex and generally ineffective mechanisms, to develop a high-voltage machine that can operate at power grid

[8] I find it interesting that ABB refers to the inventive technology as "ENKEL," which I understand means "simple" in Swedish.

voltages without the need for a step-up transformer. However, it is my observation that other companies abandoned their attempts to provide a commercial product. The work of ABB's inventors has now shifted the paradigm since they have demonstrated that high-voltage rotating machines can be implemented using a simpler design, not a more complex one. ABB has inspired others to reevaluate technological solutions for making high-voltage rotating electric machines.

35. I understand that amended Claim 77 is directed to a rotating electric machine configured to operate at high-voltages. The machine has a stator that is wound with a high-voltage cable drawn through a first slot, a second slot, and a third slot of the stator so as to form a continuous full turn of the stator winding. The machine also includes support members in contact with the stator winding. This is an unusual design because in most rotating electric machines greater than 30MW, the windings are manufactured in segments and then connected to one another in an end-winding region (outside of the stator core) by a joint. Thus, it is clear to me that one advantage of having a continuous cable as a full winding turn is that there is no need to make a joint for every turn, thus reducing manufacturing costs. Furthermore, since in conventional designs, vibrations of the end-windings draw a lot of attention by the machine designers, it would not be an obvious choice for a machine designer to substitute a flexible cable for the rigid bar windings used in ordinary high-voltage machines.

36. The high-voltage cable used for the stator windings in the present invention includes an insulation system having three layers: first, an inner semiconducting layer; second, a permanent insulation layer surrounding the inner semiconducting layer; and third, an outer semiconducting layer surrounding the permanent insulation layer. The inner semiconducting layer and the outer semiconducting layer each constitute an equipotential surface. One reason for including the outer semiconducting layer is to provide an equipotential surface that can be held at a predetermined voltage. The equipotential surface confines the electric field to within the cable, and allows the cable to minimize the risk of arcing, or partially discharging, from the cable to other surfaces. The end winding is fully insulated and thus, partial discharges in the end-winding region will be minimized.

37. In the Office Action dated September 29, 2000, it appears the Examiner rejects Claim 77 based on a hypothetical machine constructed by combining a machine having a continuous winding in Shildneck, using an insulated cable from Elton for the winding, where packing means as described in Wood are placed between the stator and the winding. For the reasons I discuss below, if I did not know about the present invention by ABB, I would not have been able to see why I, or another high-voltage machine engineer, would have been motivated to put these different pieces of prior art together as the Examiner has done. Furthermore, nobody has ever done it, besides the Examiner.

38. The Examiner uses the cable from Elton as a winding in the stator from Shildneck for the reason that the cable from Elton "would provide a cable that is flexible, prohibit the development of corona discharge and equalize the electrical charge generated between two layers." The Examiner goes further, in using the spring from Grant to secure the cable in the stator slot. In my view, this assertion is unreasonable, and must have been made without the benefit of understanding the technical and functional objectives of the present invention, Shildneck, or Elton.

39. The Examiner asserts that the machine in Shildneck teaches the machine claimed in the present application with the exception of the winding having at least one semiconducting layer around the conductor and using spring members in the stator slot to reduce vibrations.[9] In rejecting the claims, the Examiner asserts that it would have been obvious to one of ordinary skill in the art at the time of the invention to have provided in the machine of Shildneck, an electric cable as a winding having "an electrical conductor comprised of a solid insulation layer 106 between two semi-conducting pyrolyzed glass fibers 104, 110, the internal grading layer 104 surrounding the conductors of cable 100,"[10] as disclosed by Elton. The Examiner asserts that making such a combination would "provide a cable that is flexible, prohibit the development of corona discharge and equalize the electrical charge generated between two layers."[11]

40. Shildneck describes a conventional low-voltage, high-current machine. As such, the design of the machine in Shildneck does not consider the problems that exist

[9] See Office Action dated October 25, 2000, page 2, numbered paragraph 2.
[10] See Office Action dated October 25, 2000, page 3, first full paragraph.

in high-voltage machines, such as partial discharge. During my employment with General Electric (the assignee of the Shildneck patent), it was my pleasure to work with at least one engineer who, as a young man, was part of the engineering team that designed the cable-wound generator of Shildneck. The avowed goal of attempting to use a cable-like winding in the Shildneck machine was to determine if the technology might offer significant cost savings compared to the use of coils or bar-type windings at conventional voltages. Through my employment at General Electric, I became familiar with the work surrounding the machine described in Shildneck, and happen to know that this attempt failed to achieve its objectives because the system, although operable at low voltages, was not cost effective. In a discussion with the Shildneck team member mentioned above, in light of the ABB publications of the ENKEL technology, I asked him if anyone had conceived of the concept of designing this generator for higher voltages. He emphatically advised me that cost reduction at standard voltages was the only objective. I should add that Mr. Shildneck was considered one of the more creative engineers of his time at General Electric and this engineer from his team later became a leader in the design of air cooled generators. Both were significantly more advanced than "one of ordinary skill in the rotating electric machine art!"

41. The Shildneck reference does not in any way suggest the desirability of increasing the voltage. The operation of Shildneck is inherently limited to conventional voltages due to (1) the use of an insulator as the outermost layer of the winding; and (2) the lack of any type of description of how to eliminate corona between an insulated conductor and a metallic member. Corona will form in any small air packet between the insulation material and the stator slot, provided that sufficient voltage develops across the air space. When the corona builds up at these positions the insulation material will eventually deteriorate, ultimately leading to a breakdown of the machine. Machines that operate at higher voltages are usually provided with some kind of E-field control in the end-winding region. Corona protection varnish is often used. This E-field control evens out the dielectric stress of the insulation material in the end winding region, but electric field concentrations are still a severe problem in electrical machines operating at these

[11] See Office Action dated October 25, 2000, page 3, last paragraph – page 4, first paragraph.

higher voltages. Shildneck does not use an E-field control, and actually uses silicon rubber as the ground insulation, which would surely deteriorate when exposed to inevitable corona if the machine were to be operated at higher voltages. Accordingly, Shildneck is configured for use only at low-voltages.

42. I do not agree that combining the low-voltage machine of Shildneck with the cable of Elton would result in a high-voltage machine that would be operable in a commercial-usage context.

43. As the teaching of the Shildneck patent was to develop a low-voltage machine having a cable winding, the materials selected and presented in the teaching are those suitable for those ordinary high voltages. An objective of Shildneck was to achieve generator voltages from 10 kV to 15 kV (13.8kV being the most frequently used voltage for these generators). The materials used in the cable in Shildneck, although acceptable for use at these voltages, are totally unacceptable at higher voltages such as those voltages at which the ENKEL technology operates.

44. There is nothing in Shildneck that suggests to me that higher voltages are desirable, nor is there any suggestion in Shildneck that the insulation system of the winding proposed therein could be modified in order to achieve higher voltages.

45. There is nothing in Elton to suggest that the cable shown in Figure 7 thereof could be used as a stator winding in a high-voltage rotating machine. Rather, Elton is directed to a pyrolyzed glass fiber layer that can be used in several applications. One such application discussed in Elton is for providing a semi-conducting layer around conventional bar-type windings of an electrical machine to bleed off charges thereon and to minimize the possibilities of a corona discharge.[12] Another application discussed in Elton is for using the semi-conducting pyrolyzed glass fiber layer in a cable to equalize the electric charge on the exterior of the insulator of the cable.[13] These are but two examples disclosed in Elton for applying the inventive pyrolyzed glass fiber layer. It should be noted, however, that nowhere in Elton is it suggested that one could use the cable as a winding in an electric machine to replace the conventional bar-type windings to achieve higher voltages.

[12] See Elton, column 2, lines 44-48.

The use of the pyrolyzed glass fiber layer in the bar-type windings and in the cable are two disparate uses of the pyrolyzed glass fiber, no more connected in the Elton reference than are the bar-type winding and the use of the pyrolyzed glass fiber for surrounding a housing for electric equipment, shown in Figure 8 of Elton. It is the various uses of the pyrolyzed glass fiber that Elton teaches, not the use of an exemplary cable as a winding in a rotating electric machine, as is suggested by the Examiner.

46. Consequently, I cannot agree with the Examiner that it would have been obvious to one of ordinary skill in the rotating electric machine art, to combine the low voltage machine having cable windings of Shildneck with a cable used to demonstrate an exemplary use of a pyrolyzed glass fiber layer in Elton to arrive at the high-voltage machine of the present invention. Such a combination, as discussed above, would not produce an operable high-voltage machine, and certainly would not produce a machine capable of operating at the voltage levels achievable by the present invention.

47. Wood is asserted for its description of using inflatable packing means for supporting conductors in a stator slot. As shown in Figure 1 of Wood, bar-type windings 3 are supported in the stator slot 2 by both non-inflatable packers 6 and inflatable tubes 8. Aside from the packing means, there is nothing in Wood that would facilitate the combination of the low voltage machine having a cable winding of Shildneck with the cable disclosed in Elton to arrive at the high-voltage machine of the present invention.

48. Mazzorana is asserted for its teaching of various ways of forming slot shapes. Aside from the various slot shapes, there is nothing in Mazzorana that would facilitate the combination of the low voltage machine having a cable winding of Shildneck with the cable disclosed in Elton and the inflatable packing means of Wood to arrive at the present invention.

49. Grant is asserted for its description of using spring members to hold a winding in stator slots. I am quite familiar with this patent as it was developed under a program that I funded while at GE using the skills of Mr. Grant who was my

---

[13] See Elton, column7, lines 12-21.

employee. This patent was successfully applied to a large number of generators while I was at GE and since I left. As can be seen in Figure 1 of Grant, the winding 14 is a "stator bar" (col. 4, line 57) and not a cable, and thus the springs are flat and were specifically intended for generators at 30 kV or less., not in an arc shape, as would be used to support a round cable. Aside from the springs, there is nothing in Grant that would facilitate the combination of the low voltage machine having a cable winding of Shildneck with the cable disclosed in Elton to arrive at the high-voltage machine of the present invention.

50. Siemens is asserted for its teaching of having winding slots with decreasing radius in order to accommodate winding conductors having varying diameters. Aside from the decreasing radius stator slots, there is nothing in Siemens that would facilitate the combination of the low voltage machine having a cable winding of Shildneck with the cable disclosed in Elton and the inflatable packing means of Wood to arrive at the present invention. Furthermore, Siemens does not use a continuous full turn of a winding, but rather "a plurality of individually insulated slot conductors,"[14] which, among other things, facilitates the replacement of damaged conductors.[15]

51. Madson is asserted for its teaching of using relatively thin pressure tubes supplied with a thermosetting resin to expand the tube. The tube is then heated until the resin is hardened, at which point the filler tube is removed. Aside from this process of forming the support element, there is nothing in Madson that would facilitate the combination of the low voltage machine having a cable winding of Shildneck with the cable disclosed in Elton and the inflatable packing means of Wood to arrive at the present invention.

52. I further state that all statements made herein to my own knowledge are true and that all statements made herein on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both under Section 1001 of Title 18 of the United States Code and that such any willful

[14] See Siemens, col. 1, lines 19-20.
[15] See Siemens, col. 1, lines 39-40.

false statements may jeopardize the validity of the application or any registration resulting therefrom.

Robert E. Fenton

Robert E. Fenton

April 3, 2001

Dated

APPENDIX A

Resume of Robert E. Fenton

Robert E Fenton

Professional Background

1998	President, Generation Technology Consultants, Inc., Charlton, NY.
1986-1997	General Manager – Generator Design and Development Engineering, General Electric Co., Schenectady, NY 12345.
1980-1986	Manager, Generator Project Engineering, General Electric Co.
1973-1982	Manager, Generator Application Engineering, General Electric Co.
1967-1973	Generator Application Engineer, General Electric Co.

Education

1967	MS Engineering – Electric Power Engineering, Rensselaer Polytechnic Institute, Troy, NY.
1965	BS Electrical Engineering – Manhattan College, Bronx, NY.
1978	Management Development Course – RPI, Troy, NY

Experience

Technology: A recognized expert in the field of Power Generation especially generators. Fellow of the IEEE, member of international technical society committees. Have led teams in developing new products, analyzing problems on existing products (root cause analysis), generator testing and developing new service offerings.

Business Management: The GE Generator Business was a $400 million (US) enterprise inside GE Power Systems. The business strategy and operational execution was developed by a team consisting of the GM – Generator Engineering and other GM's. Continuous interaction with Marketing, a global sales team, a global network of service engineers and service facilities, as well as the operating components of production and engineering was required. Extensive interface with customers, partners and even competitors was a mode of operation. As President of GTC, Inc., I have done business development, customer interface, project management and execution.

Global Experience: The GE Generator Business has had partnership agreements with companies in Austria, Korea, China, Japan, and Taiwan. I played a very active role in the creation, structuring and relationship development of GE's generator agreements. In addition, as a spokesperson for the Business, I have met with major customers, insurance companies, partners, and competitors in every corner of the world. As the sole U.S. Delegate to CIGRE Study Committee 11, I meet at least annually with leaders from 24 major industrial countries representing manufacturers and users of generation equipment.

At GTC, Inc., customers and technical interaction are worldwide.

Business Strategy: The utility/industrial generation marketplace has been rich in manufacturing capacity in major industrial countries. This created a buyer's market with extremely stiff price competition. Cost reduction through product redesign, vendor initiatives, people productivity and manufacturing outsourcing was a way of life. As a business leader, I was involved in each.

Honors and Industry Activities:

2000	Elected Fellow of the Institute of Electrical and Electronics Engineers
1994	Distinguished Alumnus – Rensselaer Polytechnic Institute
1994-2000	US Delegate to CIGRE SC11 (Rotating Machines)
1998-present	Convenor of CIGRE Working Group 11 Turbogenerators
1986-present	Member IEEE Rotating Machinery Committees
1982-1986	Treasurer – IEEE Power Engineering Society
1978	IEEE Centennial Award
1975-1997	Author of numerous technical papers
1973-1980	Member IEEE Station Design Subcommittee

2135 Cook Rd
Charlton, NY, 12019

518-882-9906 (office)
518-882-6959 (fax)
518-882-6009 (home)
fentongtc@aol.com

Robert E Fenton
Representative Experience/Projects

Generation Technology Consultants
President, Consultant, Project Leader

1998 — Geneva Steel Co; Vineyard, UT
Led a team of five experts determining root cause of a power outage that led to major damage of the mill. Responsibility included Generator, Steam turbine, controls, exciter system, voltage regulation, circulating water system and condenser. Multiple reports prepared and presented. Deposed by Counsel for Insurance Co. Resolved favorably for Geneva Steel in mediation.

1998 — Fermi Energy Center, Monroe, Michigan
Supported Detroit Edison in an investigation and analysis of damage caused to the stator winding following a severe abnormal operation event. Developed and demonstrated relationship between damage and event.

1998 — A northern European OEM, Canadian Subsidiary
Provided an expert opinion regarding expected life of unique generator in a pulp mill application. Expert witness, deposed, litigation settlement favorable to client. May 1999

1998 — Gordonsville Energy L.P./Mission Energy; Fairfax, VA
Provided expert testimony in preparation for and at trial regarding failure of a component in a generator rotor.

1999/2000 — Major North American Electric Machine Manufacturer
Program Management of a development program related to a new technology including hiring a subcontractor to do detail component design. Product was successfully tested in Spring of 2000 and achieved all objectives.

1999 — General Electric Co., Units and Projects, Schenectady, NY
Project Management of a customer witness program involving equipment at 8 European factories and 2 US factories.

1999/2000 — Major European OEM
Provide Technical expertise in meetings with outside counsel and US Patent Office in support of patent applications with regard to prior art and State of the Art of Technology.

1999	Major European Transportation Equipment Manufacturer- USA Affiliate Provided expert opinion regarding failure of traction motors and quality of vendor supplied products.
1999	American Electric Power Co., Columbus, OH Provided Expert advice to the client in the conversion of existing steam turbine generators to Synchronous Condenser Operation.
1999/2000	Power Technology Incorporated, Fitchburg, Ma Formed a Generator Design Review Team that provided expertise to the client and their vendor who was designing a new generator for a naval application.
2000	Union Carbide Corporation Investigation, inspection and participation in a corrective plan for a generator with significant early life problems. Developed Specifications for a replacement generator and a rewind. Participated in planning and execution of generator replacement.
2000	Kelley, Drye & Warren Attorneys at Law Retained as expert witness in a lawsuit on a generator with design deficiencies.
2000	ESKOM, Republic of South Africa National Utility Formed and led a team of 4 Experts that analyzed a failure on a series of 25 year old generators that the OEM had been unable to define the root cause of. Determined root cause and published definitive report on failure mechanism.
2000	Paul, Weiss, etal. Attorney's at Law on behalf of MHI Retained as expert in Generator failure of a 700 MW water-cooled generator in China.
2000	TRIGEN-Philadelphia Investigated the failure of one coil in a 125 MW air cooled generator. Secured coil in an independent Lab, defined test program and will publish report on findings and if possible root cause.

General Manager – Generator Engineering, General Electric Co.

1986-1997 •Directed two major redesign programs for GE's generator product line ('87 & '97) aimed at enhancing customer value via performance and cost reduction to assure competitiveness to GE. Programs achieved targeted

objectives and contributed to GE's leadership position in the field of power generation.

- Directed the New Product Introduction process at GE for generators and related technology including development of market needs, product plans, cost objectives and schedule. New products included new design generators as well as service technology offerings such as GE's patented epoxy injection leak repair. Established and participated in the Design Reviews for all new products.
- Directed the root cause analysis teams investigating major equipment failures. Served as the key technology contact with involved customers. Implemented effective solutions to avoid similar repetitive occurrences.
- Personally met with customers from around the world to discuss their needs and GE product solutions.

<u>Manager, Generator Project Engineering, General Electric Co</u>.

1980-1986 Developed the replacement Generator strategy that led to the application of existing inventory on competitor's steam turbines solving technical problems in a quick and cost effective manner. This strategy was adopted by other manufacturers subsequently.

Responsible for developing guidelines for generation operation, both normal and abnormal and communication of these to customers

1967-1982 •Personally involved in the application of scores of generators into US and global power plants. Noteworthy are

American Electric Power Co. – Donald C Cook (Nuclear)
Baltimore Gas & Electric Co – Calvert Cliffs (Nuclear)
Arkansas Power & Light Co – Arkansas Nuclear One (Nuclear)
Houston Lighting &Power Co – Cedar Bayou #3 (and others)
Texas Power & Light Co – Tradinghouse Creek (and others)
Texas Power & Light Co – Monticello (unique design)
Pacific Power & Light Co – Jim Bridger (and others)
Minnesota Power &Light Co – Clay Boswell (unique design)
Arizona Nuclear Power Project – Palo Verde
Tokyo Electric Power Co – Fukushima 6 & 2 (Nuclear)
Tokyo Electric Power Co – Kashima 5 & 6
Taiwan Power Co – Manshaan (Nuclear)
Public Service Electric and Gas – Salem (Nuclear replacement generator
Union Electric Co. – Labadie (replacement generator)
Consolidated Edison Co – Indian Point (Nuclear replacement generator)

•Personally involved in Testing Programs at the following new generator designs

American Electric Power Corp - Big Sandy #2
Texas Power & Light – Tradinghouse Creek #2
Houston Power & Light – Cedar Bayou #3

Detroit Edison Co – Monroe
Detroit Edison Co – Trenton Channel #9

APPENDIX B

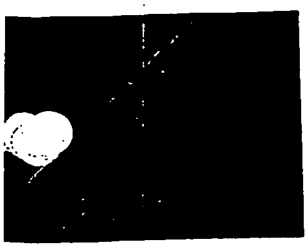
EPRI Report: High-Voltage Stator Winding Development, April, 1984

EPRI
Electric Power
Research Institute

Topics:
Superconducting generators
Electric generators
Alternators
Power transmission

EPRI EL-33
Project 171
Final Repor
April 1984

CD 037



High-Voltage Stator Winding Development

Prepared by
General Electric Compa
Schenectady, New York

E.6
6.1
6.14

Higi -Voltage Stator Winding Development

EL-3391
Research Project 1716-1

Final Report, April 1984

Prepared by

GENERAL ELECTRIC COMPANY
Large Steam Turbine-Generator Division
1 River Road
Schenectady, New York 12345

Principal Contributors
D. R. Albright, Program Manager

C. M. Stephens, A. Pletenik, J. L. Kirtley, W. Kennedy, F. E. Anderson, H. F. Sage, J. C. Appiarius, R. E. Stickle, K. G. O'Brien, S. H. Minnich, T. A. Keim, P. G. Brown, J. A. Mallick, C. W. McHenry, J. B. Archibald, J. Berdy, C. E. J. Bowler, H. W. Mosteller

Prepared for

Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, California 94304

EPRI Project Manager
J. S. Edmonds

Rotating Electrical Machinery Program
Electrical Systems Division

ABSTRACT

This report describes the work funded by the Electric Power Research Institute, Inc. for assessing the technical and economical feasibility of developing transmission-level-voltage superconducting generators for central station electric utility applications.

Section 1 provides a summary of the study and describes the purpose, objectives, and the general conclusions of the study.

Section 2 describes the monolith cylinder armature design, which was selected as the concept having the best chance of proving to be technically and economically feasible. Different component design approaches are discussed and analyzed, and final component designs are selected. Detailed generator designs are performed for two different ratings (600 MVA — 345 kV and 1200 MVA — 500 kV). The areas covered in the design study include magnetic dimensions, major machine reactances, conductor designs, cooling systems, winding arrangements, insulation configurations, and electrical and mechanical stress levels.

Section 3 describes the commercial acceptance tests necessary to qualify the insulation systems of high-voltage generators. The tests are similar to those performed for high-voltage transformers and inductive reactors, since the impulse and overvoltage duty of the high-voltage generator is similar.

Section 4 describes the power system considerations of connecting high-voltage generators directly to the transmission lines. Although some changes in normal power station auxiliary equipment will be required, there appear to be no major problems which would suggest technical infeasibility. Stability studies indicate improved critical clearing times of two cycles for high-voltage generators.

Section 5 describes several secondary high-voltage generator design concepts and the reasons for their technical and economical infeasibility.

Section 6 describes economic analyses comparing the long-term economic benefits of low-voltage and high-voltage superconducting generator development programs.

Section 7 summarizes the final design recommendation for the monolith cylinder armature and discusses the reasons for its selection and some of its known limitations.

Section 8 describes a possible follow-on hardware development program which would be necessary to confirm the results of the analytical studies discussed in this report. This follow-on development program would be necessary to better assess the technical feasibility of high-voltage generators.

EPRI PERSPECTIVE

This research project, RP1716-1, was undertaken to develop a preliminary design for a high-voltage turbine generator. When operating at transmission-level voltages, the generator stator winding is connected directly to the transmission system. The combination of improved electrical turbine generator characteristics and the elimination of the generator step-up transformer produces a net reduction in generation losses and improves system stability. If the high-voltage generator is technically feasible and if there are sufficient benefits to the utilities, follow-on development work is anticipated. The possibility of high-voltage stator windings has evolved in part from the new concept of using superconducting field windings in the turbine generator rotor. The very high magnetic field that is produced by the superconducting field winding makes it possible to configure a stator winding that can be insulated for operation at transmission-level voltages.

PROJECT OBJECTIVES

The objectives of this project were to assess the practical aspects of various high-voltage stator winding concepts and to develop a preferred design applicable to large, synchronous turbine generators in the future. Such a radical departure from conventional generator design necessitates a detailed study of all aspects of mechanical, electrical, and thermal design related to the stator. The project was structured to include a detailed feasibility study. This will determine whether or not to proceed with prototype high-voltage generator development.

PROJECT RESULTS

This study was open to generator designs that could use either a rotor with a conventionally cooled field winding or a rotor with a liquid helium-cooled field winding or a rotor with a liquid helium-cooled superconducting field winding; but the findings of this report show that only superconducting rotors are applicable for high-voltage generators. The economic studies show that high-voltage generators can produce desirable operating benefits for the utility industry. However, two items that can adversely affect anticipated benefits are higher development costs and lower reliability of high-voltage generators when feeding directly into the transmission system. Before proceeding further with a prototype high-voltage insulation system and winding development, the application of superconducting rotors will have to be successfully demonstrated.

James S. Edmonds, Project Manager
Electrical Systems Division

CONTENTS

CONTENTS (Cont'd)

TENTS (Cont'd)

ILLUSTRATIONS

ILLUSTRATIONS

ILLUSTRATIONS (Cont'd)

ILLUSTRATIONS (Cont'd)

ILLUSTRATIONS (Cont'd)

ILLUSTRATIONS (Cont'd)

TABLES

Section 1

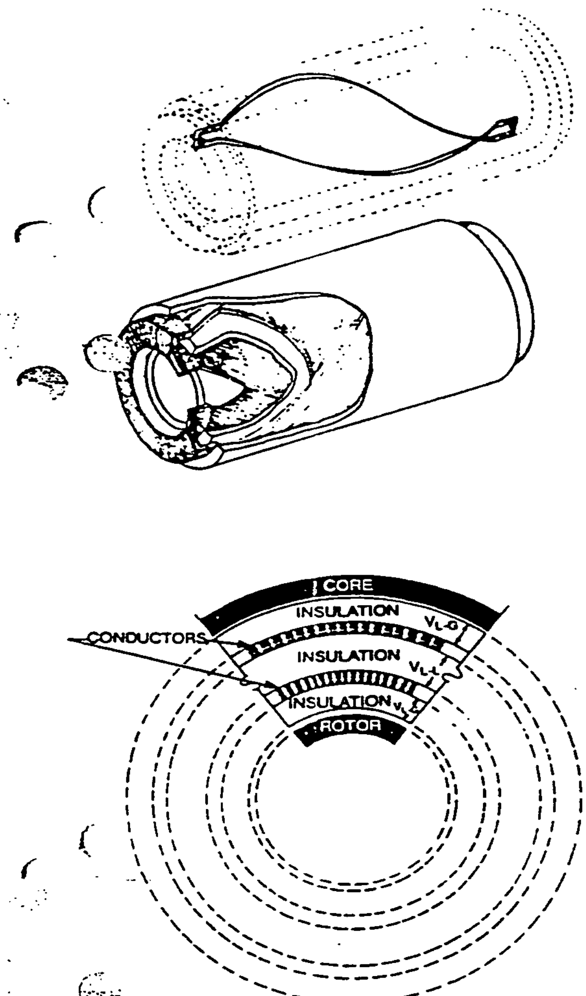
SUMMARY

Technical research and development efforts performed by the General Electric Company for the Electrical Power Research Institute under contract RP 1716 "High-Voltage Stator Winding Development" are described in this document. The goals of this research project were (1) to develop conceptual designs of large steam-turbine generators that can be connected to transmission systems without step-up transformers (Figure 1-1) and (2) to assess their technical and economical feasibility. The motivation for the development of such generators is to eliminate the purchase cost of the high-voltage step-up transformer and the operational cost of its losses. The general objectives of this research program were to—

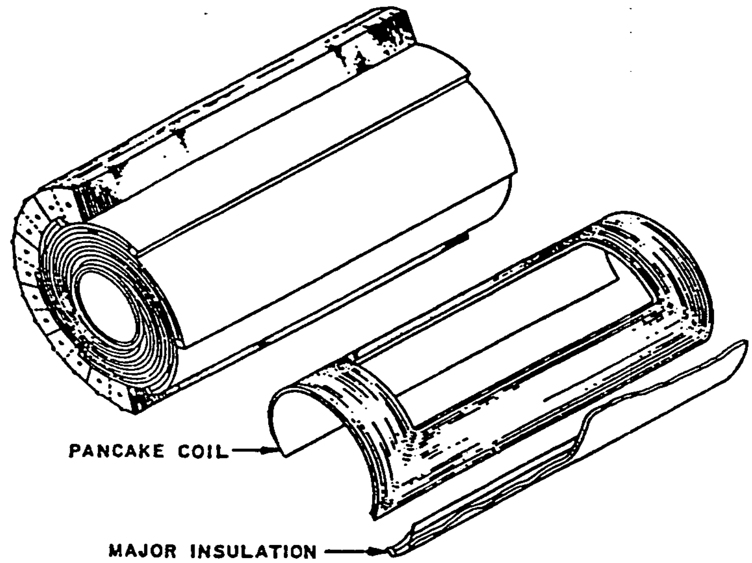
- Review the technical literature (Appendix A) to identify all published conceptual designs of generators which can be operated at transmission-level voltages (230 kV and greater)
- Propose new conceptual designs for high-voltage generators
- Perform preliminary design studies of each conceptual design to identify critical problems and to propose possible resolutions
- Perform an evaluation program to select the conceptual design having the greatest potential of being proven technically and economically feasible
- Perform as detailed a design study as possible on the selected primary conceptual design to identify its physical characteristics and limitations. Design studies were performed for two-pole units of 600 MVA, 345 kV and 1200 MVA, 500 kV ratings
- Evaluate the power system implications of high-voltage generators
- Provide a comparative economic evaluation of conventional generators, low-voltage superconducting generators, and high-voltage generators
- Identify possible follow-on development effort based on an assessment of the technical feasibility of high-voltage generators and the magnitude of their potential benefit to the electric utility industry.

The concept of developing transmission-level-voltage generators has evolved, in part, from the extensive domestic and worldwide effort being performed to demonstrate the technical feasibility of superconducting generator rotors and their economic benefits to the electric utility industry. The successful development of superconducting rotors provides a unique opportunity to seriously consider designing generators at present-day transmission-level voltages, since the large excitation capability of the superconducting field makes it possible to employ air-gap armature windings having sufficient insulation thicknesses to support the transmission-level-voltage electrical stresses. The successful high-voltage generator would eliminate the capital cost of the step-up transformer and the operational cost of its electrical losses, and rough cost savings estimates indicate that these can amount to between 10 and 14 million dollars for a 1000 MVA unit. These cost savings are in addition to those associated with the superconducting rotor's elimination of the field electrical losses. The cost savings, however, must be weighed against the development costs of high-voltage superconducting generators, and the results of economical analyses performed in this study will indicate if follow-on development efforts are warranted.

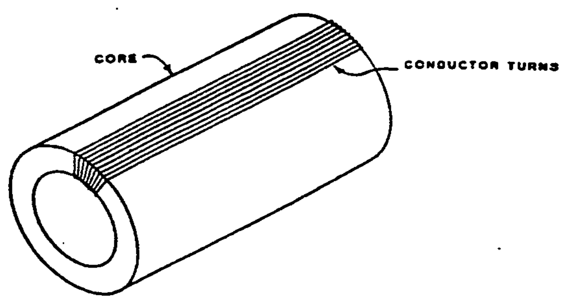
This technical study was primarily directed at exploring the high-voltage stator winding concept. No significant effort was devoted to upgrade the designs of superconducting rotors and low-voltage air-gap armature windings. However, the General Electric Company's involvement with the EPRI-sponsored development of low-voltage superconducting generators (Reference 1-1) provided in-



Monolith Cylinder Armature

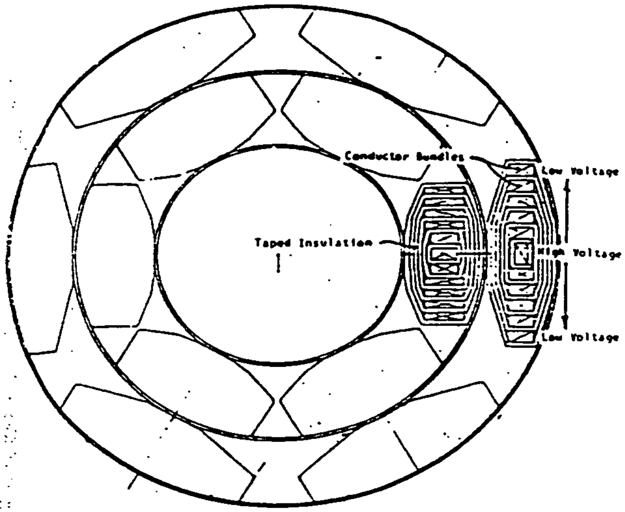


Spiral Pancake Armature

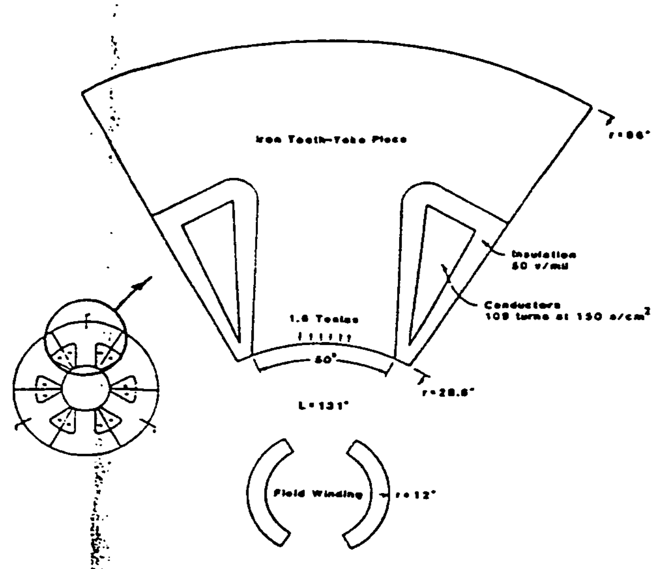


Toroidal Armature

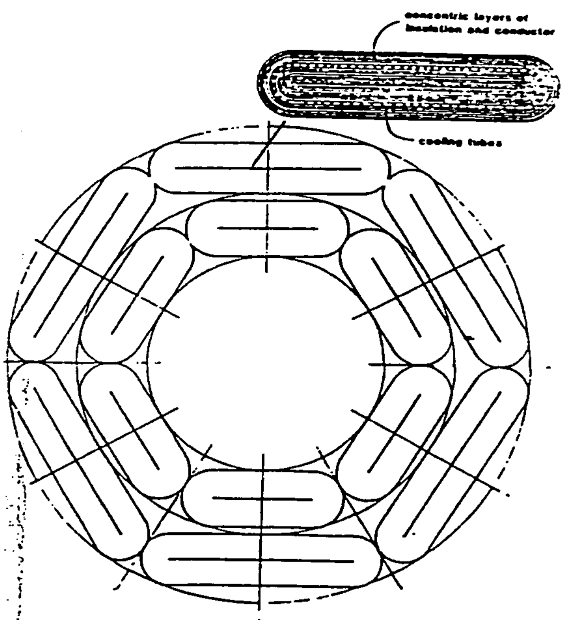
Figure 1-2. High-Voltage Generator Conceptual Designs.



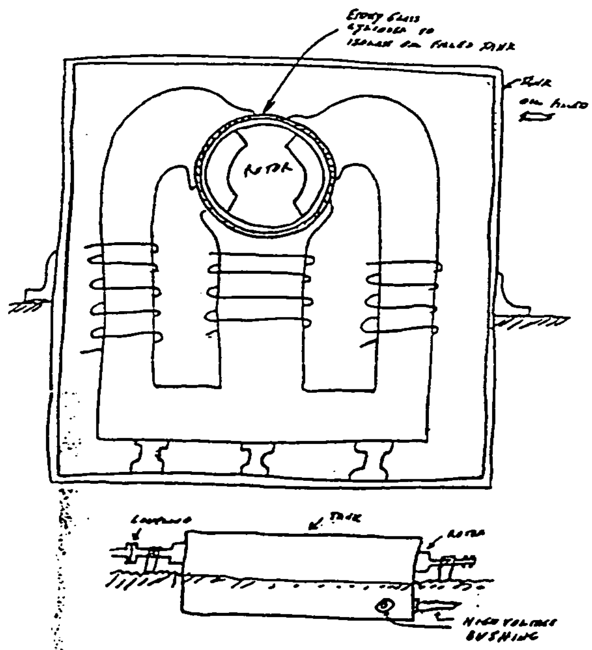
Integral-Insulated Phase Belt Armature
Taped System



Salient Pole Stator
(six magnetic poles)



Integral-Insulated Phase Belt Armature
Coaxial System



Salient Pole Stator
(three magnetic poles)

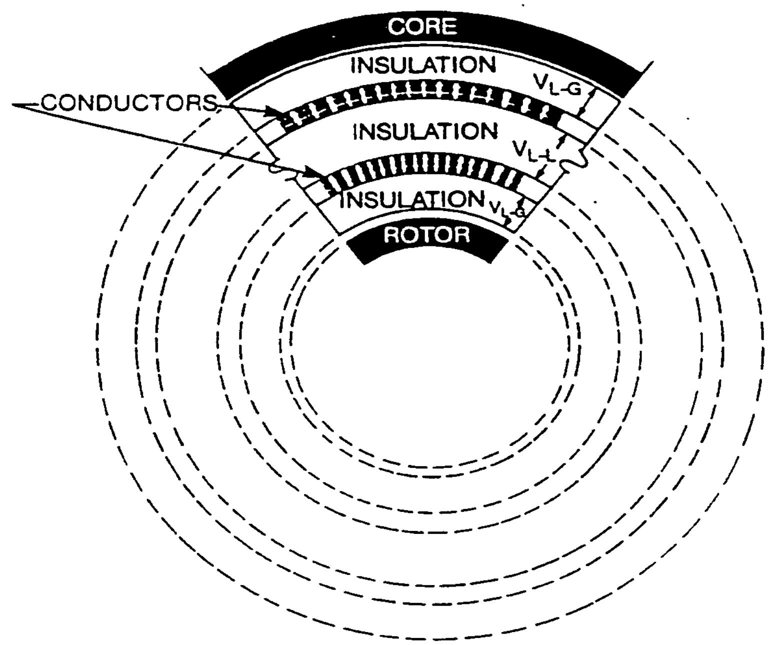


Figure 1-3. Cross-Section of the Monolith Cylinder Armature

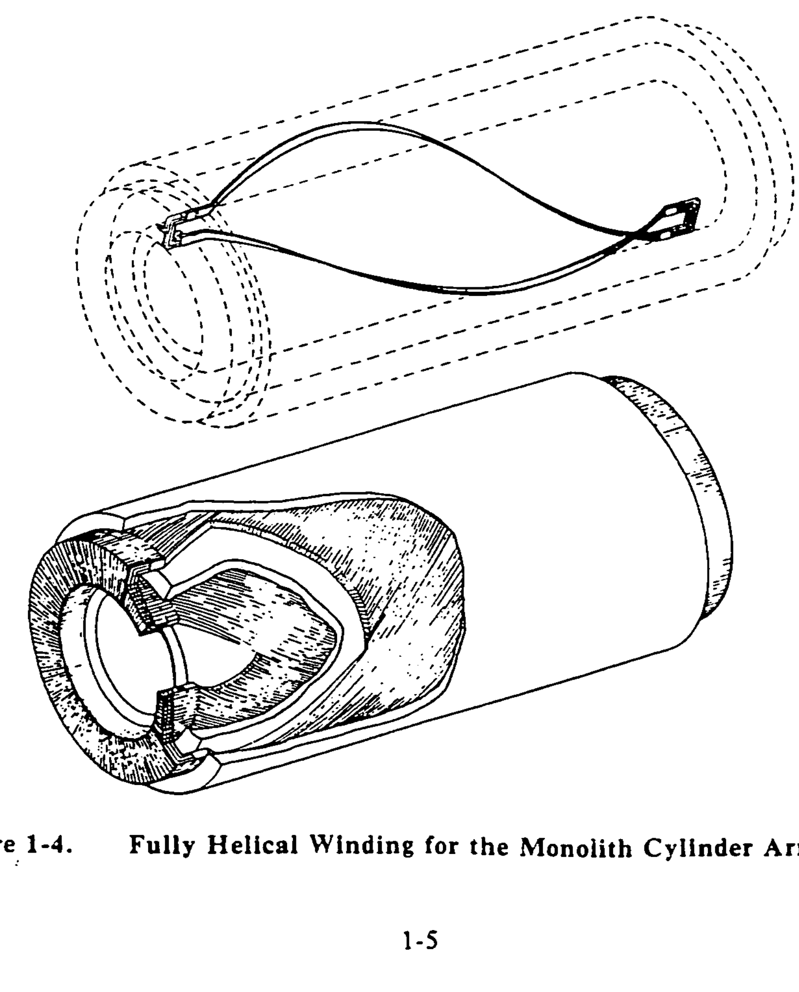


Figure 1-4. Fully Helical Winding for the Monolith Cylinder Armature

1.1.4 Generator Size Relationships

The active volume relationships of low-voltage and high-voltage superconducting generators with conventional generators are shown in Table 1-1. To provide direct comparisons between helical coil winding high-voltage generators, which have no end-winding overhangs, and diamond coil winding conventional and low-voltage superconducting generators, which have considerable end-winding overhangs, the active volumes listed in Table 1-1 are based on total winding lengths that include overhangs where applicable.

Based on these data for 600 MVA generators, the low-voltage superconducting generator is 30 to 40% smaller than a conventional generator. The 345 kV high-voltage generator is 25 to 30% larger than the low-voltage superconducting generator. The 500 kV high-voltage generator is 80 to 85% larger than the low-voltage superconducting generator and is 22% larger than the conventional generator. These size relationships reflect the poorer electrical coupling between the rotor and stator windings because of the large insulation volumes required for the high-voltage generator. The larger unit sizes required for high-voltage generators will limit the maximum generator rating which can be designed and shipped in an economical frame construction. This limit may detract from the long-term benefits of the high-voltage generator concept.

1.1.5 Generator Electrical Losses

Calculated electrical losses of high-voltage superconducting generators are of the same order of magnitude as those calculated for low-voltage superconducting generators. The electrical losses of both superconducting generator approaches are significantly less than those of conventional genera-

Table 1-1

ACTIVE VOLUME RELATIONSHIPS
600 MVA GENERATORS

Generator Design	Core Diameter Inches	Total Winding Length Inches	$D^2L \times 10^6$	Per Unit
Conventional (22 kV) Diamond Coil Winding	–	–	2.52	1.0
L-V Superconducting (24 kV) $X_d' = 0.2$ Diamond Coil Winding 150 A/cm^2 Current Density	105	153	1.69	0.67
H-V Superconducting (345 kV) $X_d' = 0.27$ Helical Coil Winding 300 A/cm^2 Current Density	111.2	173	2.14	0.85
H-V Superconducting (500 kV) $X_d' = 0.27$ Helical Coil Winding 300 A/cm^2 Current Density	119	217	3.07	1.22

- Superconducting Generator Designs Use 50 V/mil Insulation Stress
- Total Winding Lengths Include Diamond Coil End-Winding Overhangs.

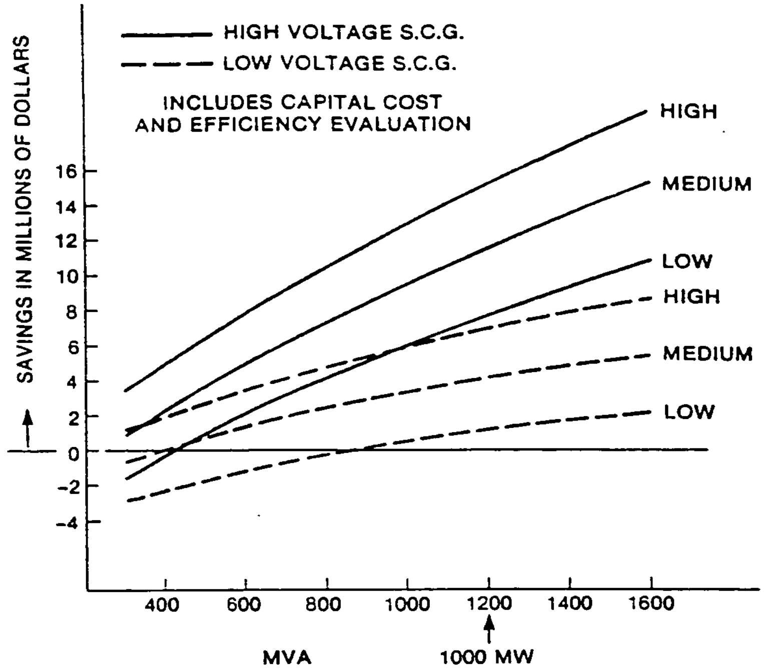


Figure 1-6. Potential User's Savings for Superconducting Generators

- Economic analysis sensitivity studies accounting for a number of different electrical growth rate, cost savings, and development cost scenarios over a thirty five year period (1986-2020) provided a wide range of potential economic savings to the electrical industry for both the low-voltage and high-voltage superconducting generator development programs. The results are, as might be expected, very sensitive to all the variables, and the reader should review the data and judge the merits of the rationale used to produce the variables. Two similar electrical growth rate scenarios using average unit cost savings estimates provided a present worth savings (1985 dollars) of 144 million dollars for the low-voltage superconducting generator development program and 375 million dollars for the high-voltage superconducting generator development program. The breakeven years were 2011 and 2010 respectively. Rates of return on development costs were 11% and 13% respectively.

1.1.8 Technical Assessment

High-voltage superconducting generator concepts represent radical departures in design and construction from the concepts used in low-voltage superconducting generators, since the stator windings will be significantly different than what is used in low-voltage superconducting generators. Although the high-voltage stator windings will use many of the known high-voltage step-up transformer technologies, the winding support system and the electrical stresses on the insulation system are different from any known similar applications. Preliminary designs and analyses presented in this report have uncovered and solved a great number of potential design problems. However, final assurance of commercial feasibility will depend on operating experience with machines of at least the mid-range of commercial ratings.

Since operating experience on large superconducting generators can not be obtained by a natural evolution of larger and larger ratings, as has been the case with conventional generators, a series of rapidly escalating rating sizes will be required to prove that low-voltage or high-voltage supercon-

Electrical creepage situations within the armature body and at the armature end regions are evaluated. The electrical creepage at the armature end regions is strongly controlled by the thickness of the insulation cylinders. Generator voltage ratings greater than 500 kV may not be possible because of the excessively thick insulation cylinders required to control the end region electrical creepage.

Conductor and conductor cooling designs are described for three proposed dielectric fluid coolants: transil oil, Freon 113, and silicone oil. The conductors are comprised of braided copper filaments and are cooled through stainless steel cooling tubes that are interspersed throughout the winding. Cooling performance is evaluated in terms of allowable temperature rises, coolant flow, and coolant pressure, among other quantities.

Large turn-to-turn voltages that are produced by voltage surges such as lightning strikes are calculated. The surge voltage distribution within the high-voltage generator is similar to that experienced by high-voltage step-up transformers. The calculations are used to qualify the armature turn insulation.

A conceptual stator frame design that will accommodate larger diameter cores than do present conventional frame designs is described. Such a frame will be important in implementing high-voltage generators because of the large magnetic dimensions of high-voltage generators. The stator frame will be required to be hermetically sealed to guard against moisture contamination of the high-voltage insulation.

The design studies performed in this section strongly suggest that the monolith cylinder armature is technically feasible. However, this conclusion is based on the results of analytical models which have not yet been fully calibrated. Also, a few potential problems which could not be modeled and analyzed — such as the effects of thermal expansion forces and the effects of long-term insulation shrinkage — were not addressed. Therefore, the final assessment on technical feasibility will require extensive model testing and operating experience.

1.3 COMMERCIAL ACCEPTANCE TESTING

Section 3 describes the methods and equipment required to test the integrity of the high-voltage stator winding insulation system. Insulation testing is emphasized in this section because the insulation tests are significantly different than those presently required for low-voltage generators, while the electromagnetic and mechanical tests can be essentially the same. The tests and test procedures outlined in IEEE Standard 115 "Test Procedure for Synchronous Machines," should generally apply with the exception of the stator winding insulation testing references.

The dielectric system of the high-voltage generator is similar to that of a high-voltage step-up transformer, and the operating environment is also similar, particularly with respect to exposure to lightning strikes and switching surges. Therefore, the recommended insulation tests for the high-voltage generator are the same as those for a transformer, namely the impulse test and the overvoltage test. The impulse test simulates the effects of lightning strikes and switching surges. The overvoltage test holds a twice-rated voltage on the winding for a specified short amount of time (typically 7200 cycles).

The impulse test can be performed in almost the same manner as performed on transformers and will use the same testing equipment. The overvoltage test will be similar to that prescribed for large inductive reactors and is called a series-resonance test. This test has capacitor banks connected in series with the generator winding. The circuit is driven with a small high-frequency (240 or 420 Hz) motor-generator set. When the capacitive reactance is tuned to the generator reactance, the voltage across the generator winding is cancelled by the voltage across the capacitor bank, and the high-frequency alternator appears to be operating in short-circuit, except for a voltage drop due to circuit losses. The high-frequency excitation limits core overfluxing and reduces the circuit current required to achieve twice-rated voltage on the generator winding. For a delta-connected high voltage generator, this test must be performed in three-phase, tripling the cost of the test equipment. The high-frequency motor-generator set must supply all circuit losses and may have to be as large or larger than any such set built to date.